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Insect Infestation of Stored Food Products in Nigeria

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INSECT INFESTATION OF STORED FOOD PRODUCTS IN NIGERIA

Report of a Survey, 1948-50, and of Control Measures adopted

LONDON: HER MAJESTY'S STATIONERY OFFICE
1952

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LIST OF STAFF

LAGOS—

Mr. G. S. Cotterell, Leader of Survey.
Mr. K. G. Smith, Control Entomologist.
Mr. H. M. B. Somade, Control Chemist.

KANO—

Mr. R. W. Howe, Senior Control Entomologist.
Mr. L. A. W. Hayward, Senior Control Chemist.

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FOREWORD

The accompanying report summarises the results of a survey lasting over two years by a team working in Nigeria to determine the most efficacious methods of controlling pests of cocoa beans, palm kernels, groundnuts and other stored foods awaiting shipment to the United Kingdom and other countries.

The survey was initiated on the advice of the Stored Products Sub-Committee of the Committee for Colonial Agricultural, Animal Health and Forestry Research, and its cost was financed by grants from Colonial Development and Welfare Research funds. The team was led by Mr. G. S. Cotterell, formerly Senior Entomologist in the Gold Coast Department of Agriculture, and the present report has been compiled mainly from material provided by him and by Mr. R. W. Howe, who was seconded for service with the team from the Pest Infestation Laboratory of the Department of Scientific and Industrial Research. The preparation of the material for publication was greatly assisted by Dr. W. F. Jepson, of the Imperial College of Science and Technology.

The recommendations made in the report on improved storage practice and control measures should be of considerable value and assistance to all concerned with a matter of great consequence to world food supplies.

Colonial Office,
The Church House, Great Smith Street, S.W.1
June, 1951.

WEST AFRICAN STORED PRODUCTS PEST INFESTATION SURVEY 1948 to 1950

A Report on Nigerian Cocoa Beans, Palm Kernels, Groundnuts and Miscellaneous Stored Products

INTRODUCTION

1. During recent years, regular inspections have been carried out by the Infestation Control Division of the Ministry of Agriculture and Fisheries on imported cargoes of stored products at United Kingdom ports. These have revealed insect pest infestations of varying degrees of severity from various countries of origin, both inside and outside the Commonwealth. Sporadic unchecked infestations of this nature are a potential source of serious danger to the national food reserves, owing to the damage resulting both from continued development of the pest insects in the infested cargoes and from direct or indirect contamination of clean produce. Several factors have combined in recent years to make pest infestation control an essential sequel to the production of export crops throughout the world. Three of the most important are: (i) the increasing need to conserve scarce food materials; (ii) the attendant insistence on higher standards of cleanliness; (iii) the use of public funds in bulk buying operations.

2. Satisfactory infestation control cannot normally be introduced as an established technical routine in the first instance. Usually it must be preceded by research projects of a high scientific and technological order, adapted to the requirements of local conditions.

Accordingly, in 1946 the Colonial Office decided to begin a series of studies designed to reduce to appropriate routines the protection of foodstuffs during shipment from the production areas and whilst in storage in the producing country.

3. As a first step, the West African Stored Products Pest Infestation Survey was organised for the purpose of collecting, by means of inspection and experiment, relevant information which would advance the interests of the West Coast Colonies as producers, and of the United Kingdom as shipper and consumer of certain essential foodstuffs. The final object of the survey was to compile and present to the appropriate authorities data as to the nature and sources of insect danger, and to recommend those methods of control which might prove best adapted to West African conditions.

4. After a preliminary inspection of the main West African territories from September 1946 to March 1947 by the leader of the Team, G. S. Cotterell, it was recommended that the Survey should be carried out in Nigeria, where the three principal West African export crops—cocoa, palm kernels and groundnuts—all present major infestation problems in transit and bulk storage. It was also recommended at that time that problems involving native food crops produced for local consumption be dealt with as a separate issue.

The Pest Infestation Survey was organised in 1946 on the recommendation of the Stored Products Research Sub-Committee of the Committee for Colonial Agricultural, Animal Health and Forestry Research with an establishment of a Leader, two Control Entomologists and two Control Chemists. Owing to difficulties of recruitment, the team did not become operational in Kano until May, 1948, and in Lagos until August, 1949. The survey was financed from funds provided under the Colonial Development and Welfare Act and administered by the Nigerian Government. Investigations were carried on from two centres presenting typical but different kinds of problems—the port of Lagos with its hinterland cocoa areas, and the up-country groundnut centre of Kano.

TERMS OF REFERENCE OF SURVEY

5. In general, there were three main lines of work concentrated in Nigeria: —

(A) Survey of species of insect present in the three main crops, with some assessment of losses.

(B) Biological work on the main pest species in the field.

(C) Investigation of control measures with a view to prescribing control routines.

6. A programme of investigational work on the above lines was drawn up in consultation with a Working Party of the Stored Products Research Sub-Committee, under the chairmanship of Professor J. W. Munro. The following points were to be investigated in detail: —

(*a*) The insects responsible for the infestation of export produce and their habits.

(*b*) The sources of primary infestations, and the origin and extent of cross infestation in storage and transit.

(*c*) The assessment of losses during storage.

(*d*) The factors influencing the mass increase of insect populations.

(*e*) Experimental testing of control methods and the extension to large scale practice.

(*f*) Possible contamination and taint of produce by control methods.

7. In general, in primary producing countries there are two aspects of the infestation problem: —

(A) The long term losses in the country of origin, affecting the local producers and merchants.

(B) The immediate problem of sudden outbreaks, chiefly affecting the United Kingdom buyer and consumer, but also of serious concern to the local Authorities.

When the Survey began operations in Kano, it soon became obvious that immediate measures for the control of the flour beetle *Tribolium* in groundnuts would have to take precedence over the investigational work. The sudden outbreak of the khapra beetle *Trogoderma* in groundnuts, and the increasing incidence of the tobacco beetle *Lasioderma* in cocoa, still further emphasised this need.

In deference to this problem, large scale practical control measures were instituted promptly and ran concurrently with experimental work.

THE TERRITORIES, THEIR CLIMATE AND CROPS

8. The location of the four West African Territories in relation to each other is shown in the map (Fig. 1.). There are two main climatic areas, each with its typical crops.

(A) The tropical rain-forest belt is well developed in Nigeria and the Gold Coast, attaining a maximum width of 200 miles. In such areas the main food crops are cassava (Manihot), yams, plantains and maize. In Sierra Leone rice is the staple food. The export crops are cocoa and palm products.

(B) The African savannah regions of the Gambia, and the northern inland parts of the other territories, have long dry seasons with the dry Sahara wind, the "harmattan". The staple food crop in these areas is guinea corn, with groundnuts as the main cash crop.

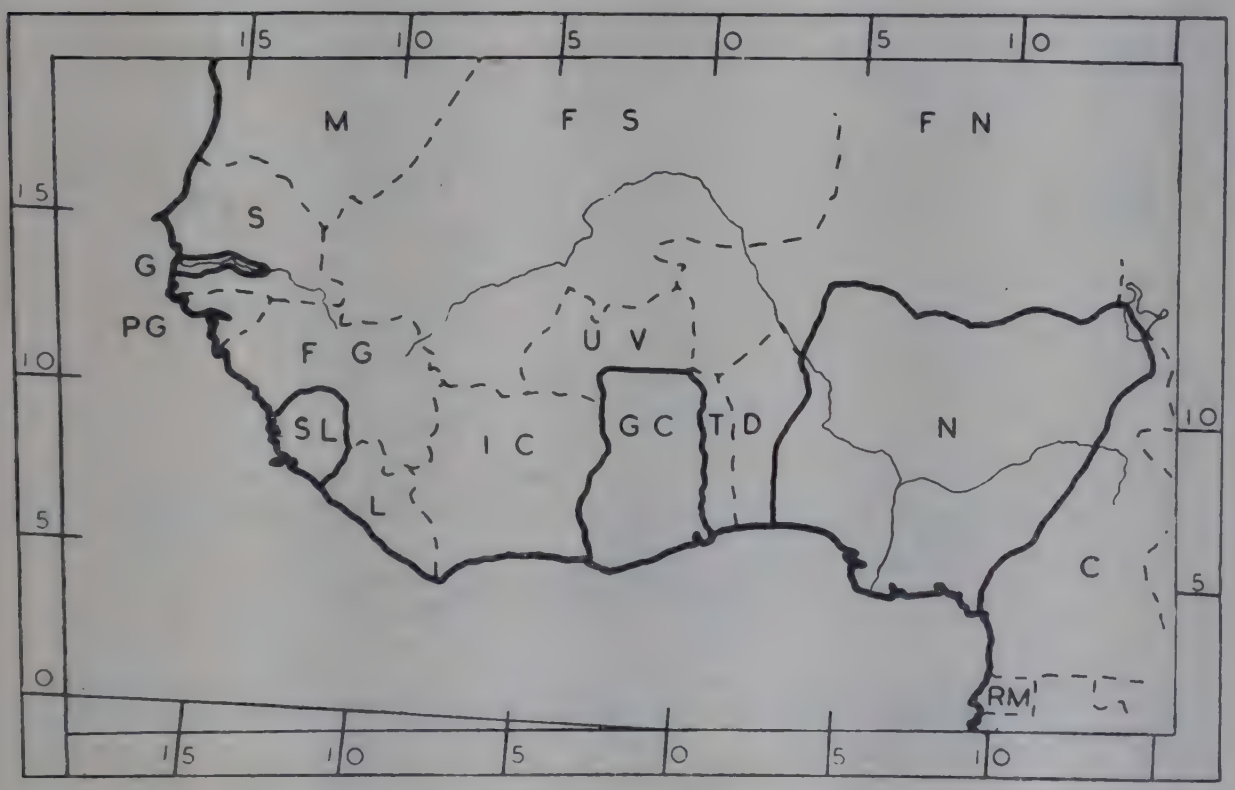

FIG. 1. *Map showing relative positions of the British Colonies (N.=Nigeria, G.C.=Gold Coast, S.L.=Sierra Leone and G.=Gambia) and neighbouring territories (M.=Mauretania, F.S.=French Sudan, F.N.=French Niger, S.=Senegal, P.G.=Portuguese Guinea, F.G.=French Guinea, U.V.=Upper Volta, L.=Liberia, I.C.=Ivory Coast, T.=Togo, D.=Dahomey, C.=Cameroons and R.M.=Rio Muni.)*

9. There is a clear contrast betweeen these two climates. The 'shape' of the climates with that of Kew, England, for comparison, is shown by the climatograph (Fig. 2), in which mean temperatures and humidities are plotted for each month of the year in the form of a closed curve. In the coastal areas, where cocoa and other goods in transit are stored, maximum temperatures are equable (82°—94°F) and humidities high throughout the year (90 per cent. and over).

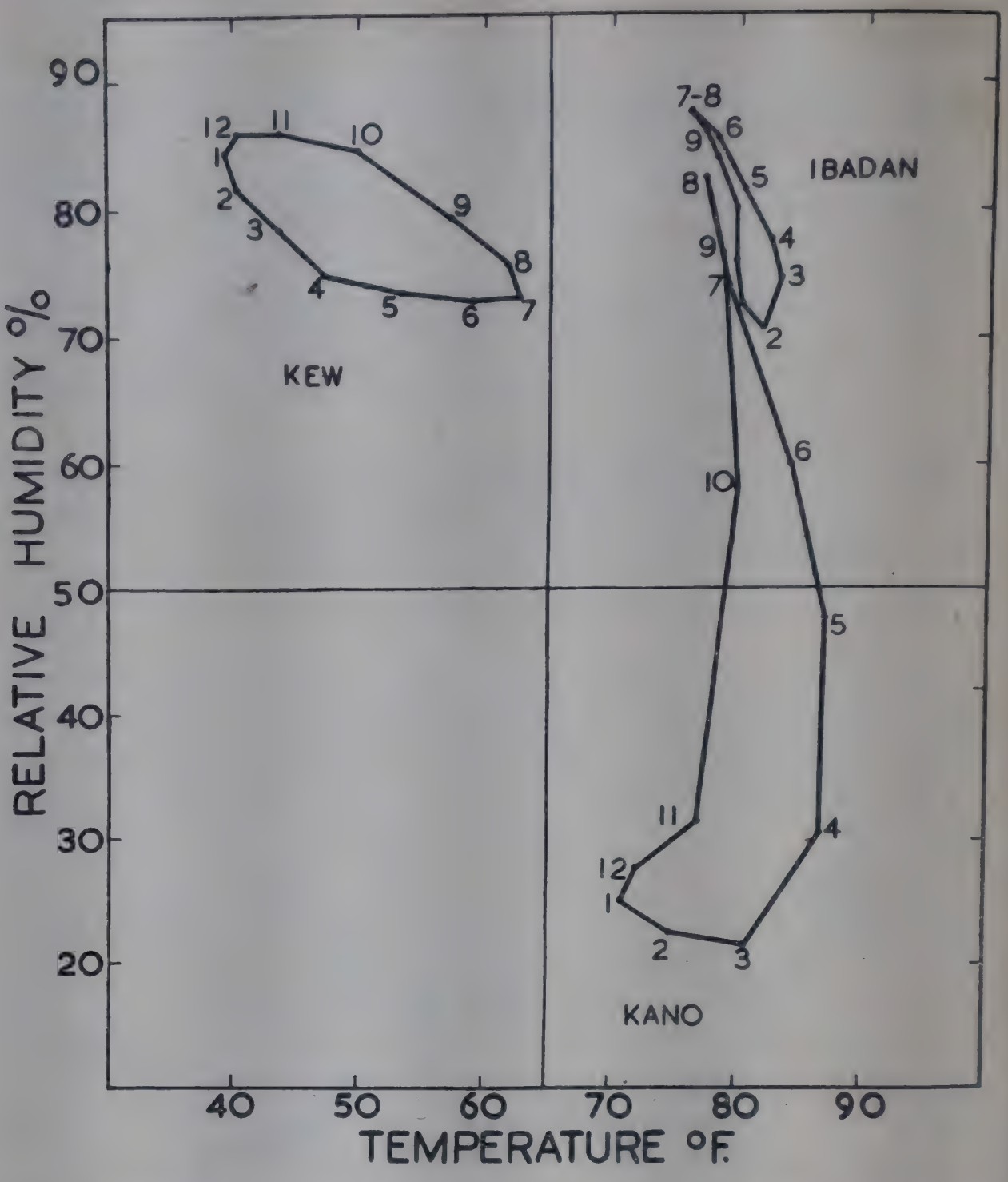

FIG. 2. *Climatographs of a cocoa centre, Ibadan; a groundnut centre, Kano; and Kew, England, using figures supplied by the Nigerian Meteorological Dept., and for Kew, taken from Bilham* (1938).

10. In the groundnut areas the maximum temperature range is greater (85°—101°F), with large diurnal fluctuations taking the temperature as low as 56°F in the cool season—(December). Humidity varies from 18 per cent. in February to 81 per cent. in August. The moisture relations of stored produce are closely bound up with the physical condition in these two distinct regions. Fig. 3 shows the relation between air humidity and moisture content for cocoa and groundnuts, with wheat as a comparison.

Differences between the pest fauna may be explained by the divergent breeding optima of the various species.

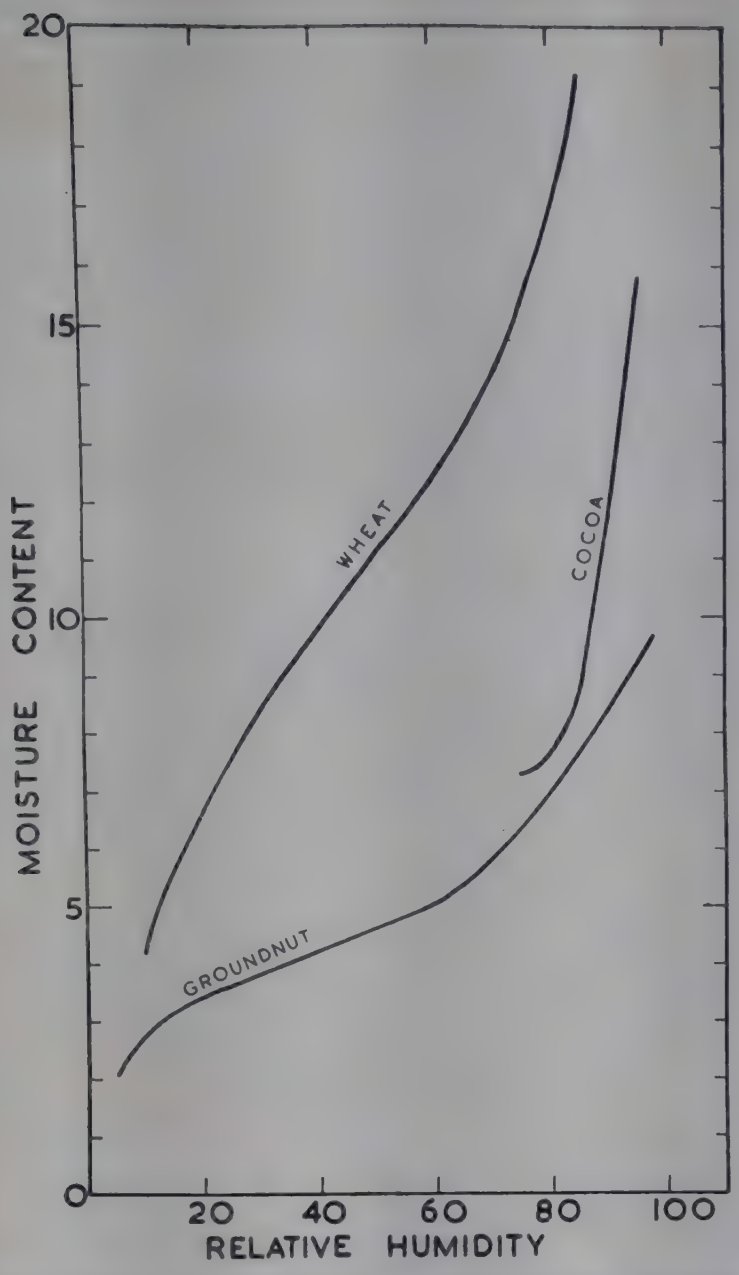

FIG. 3. *Equilibrium curves of moisture content and relative humidity for cocoa (from Scott, 1928), groundnut (original) and wheat (supplied by Pest Infestation Lab.).*

11. From the economic standpoint, the infestation problem can be put into proper perspective for each territory by quoting the average annual production of the chief export crops in round figures (tons).

	Nigeria	*Gold Coast*	*Sierra Leone*	*Gambia*
Cocoa ...	100,000	250,000	600	—
Palm kernels ...	350,000	—	70,000	1,000
Groundnuts ...	300,000	—	100	60,000 (unshelled)

Cotton, benniseed, shea, ginger and copra are produced in small quantities and carry a similar insect fauna in storage.

12. Wide annual fluctuations in production may greatly affect practical control problems. Owing to transport difficulties a large accumulation of groundnuts occurred at Kano in 1948-49, with the result that they became badly infested. This hold-up was overcome in 1950, partly owing to improved transport and also because the groundnut crop was very light.

13. The figures given above in paragraph 11 do not take into account the great problem of increasing central storage of local foodstuffs, for feeding urbanised areas. The Gold Coast authorities, for instance, are faced with the difficult problem of storing maize at a centre in the rain-forest belt for supplying Accra and other towns. Individual storage of foodstuffs by Africans is a serious potential source of infestation of export crops.

14. Production of all the major crops is in the hands of small African growers who cultivate units of an average size of ½ acre. A five acre farm would be a large individual holding, and would have to include guinea corn, maize or other food crops.

15. Preparation of the crop, i.e., drying and shelling of groundnuts, and the fermentation and drying of cocoa, is done by the peasant farmer, who brings his produce to a primary market for sale, usually to a middleman, who in turn transports it to a rail or river head. At this point it comes into the control of large buying firms or Government-controlled agencies.

These three points where storage for a longer or shorter period must take place are shown diagrammatically for Nigerian cocoa and goundnuts in Fig. 4.

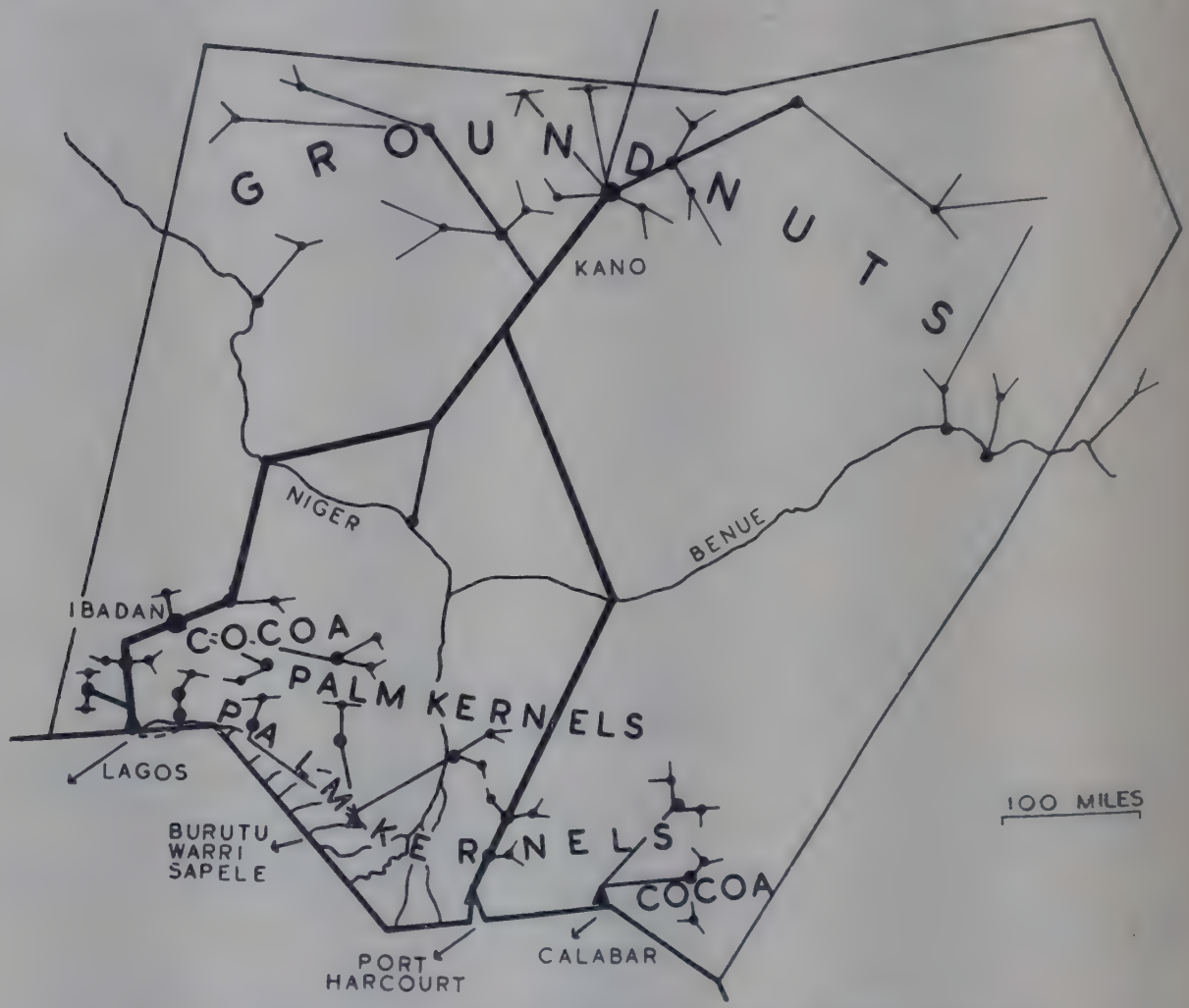

FIG. 4. *Diagrammatic map of Nigeria showing growing areas and evacuation routes of main export crops.*

16. Evacuation to ports is by rail or river in most territories, and this creates important infestation problems where congestion of the railways, with infested rolling stock, is liable to occur periodically. About 10,000 tons of groundnuts are railed monthly in open wagons to Port Harcourt and Lagos.

17. Where evacuation is by road, as in Nigerian and Gold Coast cocoa, delay seldom arises, as the main routes are all-weather roads and are not subject to restrictions during wet periods, which are such a factor in East and Central Africa.

18. Port facilities include transit sheds at the main ports, Port Harcourt, Lagos, Accra, Takoradi, Freetown and Bathurst, where unfavourable storage conditions are liable to occur. Stores are all ventilated and wide open to cross infestation, and as the produce is normally held in store for periods of only

about 14 days, warehouse hygiene and stacking tend to be below the standard required for the prevention of infestation.

19. Shipment by the main shipping companies is chiefly to the United Kingdom and is normally in bags, but in recent years up to 50 per cent. of the Nigerian groundnut crops has been shipped in bulk. The successive loading of exports at West Coast ports is an important source of cross infestation.

COCOA AND PALM KERNELS

20. Cocoa in Nigeria is grown in the rain-forest belt within less than 200 miles of the coast (Fig.4). The average holding is from ½ to 1 acre, tree density being about 500 to the acre. The tree yields two crops per year when young; the first crop, known as the "light" crop, is harvested during the rains, from May to July, and the second, main "standard" crop, from October to December.

MARKETING

21. Marketing is nearly continuous but there is an interval of three weeks between light and standard crops, during which time the cleansing of stores in producing areas is statutory. The dangerous tendency to evade the purpose of this moratorium will be referred to later in Paragraphs 23 and 24. The two crops are distinguished commercially by size of beans and the higher price realized for the main crop, which constitutes at least 80 per cent. of the total production in all Territories.

STORAGE

22. Storage structures as they affect liability to infestation can be classified into four distinct categories: —

(A) Farmers' stores.
(B) Middlemen's stores.
(C) Up-country shipping agents' stores.
(D) Port transit stores.

23. A. *Farmers' stores* usually consist of mud and wattle dwelling houses in which may also be kept local food produce. The dried cocoa beans are bagged in 60-lb. head loads if stored at some distance from a road, and are stored for periods of a few weeks only, subject to a tendency to hold back inferior unsaleable cocoa for subsequent disposal by mixing with higher grade beans. The Gold Coast has more advanced standards in this form of storage than the other Territories, perhaps owing to greater returns in the past.

24. B. *Middlemen's stores.* These stores consist of mud and wattle rooms with earth floors and thatched (more usual in Nigeria) or corrugated iron (Gold Coast) roofs. They may be attached to dwelling houses or retail shops. Middlemen are African in Nigeria and the Gold Coast, but in Sierra Leone 70 per cent. of this business is in the hands of Syrians. The more enlightened and prosperous middlemen and native co-operatives maintain stores of a higher standard constructed of cement with concrete floors. The tendency to hold back unsaleable stocks is greater here and affects a larger tonnage.

25. C. *Up-country Shipping Agents' stores.* These are maintained chiefly by the larger European shippers, the African co-operatives, and latterly by the wealthier African merchant. Stores in main centres are of a higher standard of construction in cement or brick with iron roofs. In smaller centres many stores are of all iron construction or of "swish" (local laterite) walls with iron roofs and cement floors.

26. D. *Port Transit stores.* The Government transit sheds at Lagos (Apapa) and Port Harcourt, represent the best type of premises, but in general the standard is lower than that of up-country stores, the buildings are older, and are

in any case designed for short periods of storage only. Since transit stores act as a buffer between up-country merchant and ship, they are never empty.

27. One feature common to all West African storage is the provision of extensive ventilating openings, which in many cases appear to be of questionable value since they allow free passage of insects between stores.

28. Palm kernels are produced in the forest and coastal belts (Fig 4) and are marketed in the same way as cocoa. The two crops are stored and shipped side by side.

GROUNDNUTS

29. Groundnuts are grown all over the drier areas to the north of the Niger and Benue Rivers, both in Nigeria and the neighbouring French territories on the edge of the Sahara.

30. The average native holding seldom exceeds five acres, but of this only about half an acre is planted to groundnuts, the remainder being used for guinea corn and other local food crops.

31. Groundnuts are planted with the establishment of the rains in April or May, and are harvested in October, after which there is normally no further rainfall whatever.

32. The nuts are dried and threshed in the field, and shelled in the villages by the women, either by beating with sticks or by pounding in wooden mortars. This process leads to considerable breakage, amounting roughly to one-third of the total, and, further, to a simple splitting of another one-third of the nuts (splits).

MARKETING

33. Marketing begins early in November on a date fixed by the Marketing Board* according to drying conditions. Nuts are brought by donkey or camel in loads of 200-300 lbs. to gazetted buying centres of which there are over 100 distributed through the area indicated in Fig. 4.

34. The buying centres are open platforms where the nuts are scattered and mixed, and then bagged up after weighing and examination by agents or middlemen appointed by the big buying firms. Buying continues until April, but 70 per cent. of the crop comes in during the first two months.

STORAGE CONDITIONS

35. The same four categories of storage, which have already been described for cocoa, obtain for the groundnut crop of Northern Nigeria. There are a number of special points of distinction which should be noted: —

(A) Farmers' stores are seldom used for the export crop which is marketed immediately for ready cash. Seed and food requirements alone are retained in the houses.

(B) Middlemen's storage is mainly in the open air, the bagged nuts being stacked directly upon the ground in rectangular heaps. Dunnage in the form of groundnut husk is occasionally used for protection against termites.

(C) Up-country stores exemplified by those at Kano (Fig. 5) are of much the same standard as those described for cocoa. Recently, however, a new and important development has emerged in the stacking of bagged groundnuts in open air pyramids built on stone plinths (Figs. 6 & 7).

The capacity of the stores is usually 600 tons, and that of the average pyramid 750 tons. Latterly, cottage-shaped stacks of upwards of 1,500 tons have tended to replace the pyramids. Open air stacks are covered during the wet

*The Nigerian Groundnut Marketing Board was established by legislation in 1948 as an independent organisation. It is responsible for marketing the exportable surplus crops and for promoting the development of the industry.

period, April—October, by rick sheets (Fig. 8). The high peripheral temperatures reached on such pyramids, and exposure to light, appear to render them less favourable than the closed warehouse for insect development. This fact, together with the greater practical ease of fumigation, leads the entomologist to favour such structures, and their general acceptance would doubtless reduce damage.

INSECT DAMAGE TO STORED CROPS

INSECTS DAMAGING COCOA AND PALM KERNELS

36. The damage by insects to cocoa in West Africa is not great when related to the large populations of insects in cocoa stores. Damage is shown by a fall in quality as reflected by downgrading.

The damage to palm kernels is relatively negligible but this commodity is a source of considerable cross infestation to other products.

37. Surveys in the storage premises listed above have shown the following major infesting insects: —

1. *Ephestia cautella* (Wlk) the West African Cocoa Moth or Fig Moth.
2. *Lasioderma serricorne* (F) the Tobacco or Cigarette Beetle.
3. *Araecerus fasciculatus* (de G.) the West African Cocoa "Weevil".
4. *Necrobia rufipes* (de G.) the Red Legged Ham Beetle or Copra Beetle.

A list of the more important species recorded with an indication of their abundance is given in the Appendix.

Ephestia cautella (Wlk)

THE FIG MOTH

38. This species shares with *Lasioderma* the status of chief cocoa pest in Nigeria. It is of world-wide distribution in the tropics, but does not readily overwinter in European conditions. *E. cautella* has been constantly confused with *E. elutella* (Hbn) a species more characteristic of temperate climates, and occurring in Europe as a pest in cocoa warehouses (Richards & Thompson 1932). *E. elutella* has not been found in the present Survey, and allegations made in the past that West Africa was the source of specimens found on arrival in the United Kingdom may now be regarded as erroneous.

39. The investigation into the field biology of *E. cautella* has indicated that the high populations of the moth associated with relatively slight damage to cocoa beans can be attributed to the feeding habits of the larvae, which are able to complete their development on fragments of mucilage adhering to the testa of cocoa and palm kernels, and on the dust and debris in bags and warehouses. The use of second-hand bags, especially groundnut bags, is thus a dangerous and avoidable source of infestation.

40. The moth flies in the open in large numbers at dusk and can be found at all times in dark places in a store. Larvae of *E. cautella* can only gain access to cocoa beans in which the testa is damaged by breakage, by other insects, or by germination, the latter being the most frequent defect. Infestation by larvae is confined to the peripheral bags in undisturbed stacks, and this species does not migrate prior to pupation to the same extent as *E. elutella* (but cf. Oxley, 1950, p. 21).

41. The life cycle is normally about 65 days throughout the territory, and as breeding is continuous, there will be five or six generations in the year with a consequent steady build-up of population, unless the increase is checked by natural factors such as parasites.

Lasioderma serricorne F.

THE CIGARETTE AND TOBACCO BEETLE

42. This species is at present a serious potential pest of cocoa in Nigeria. In Europe it generally does not survive the winter in unheated premises. Infestation by *Lasioderma* was first recorded in Nigeria by Golding in 1930 at Ibadan. This record is coincidental with the establishment of a large cigarette factory in Ibadan, using both local and imported leaf. It has been necessary to maintain continuous routine control measures at this factory for many years.

43. In the Gold Coast *Lasioderma* had already been recorded several years previously by Cotterell, but is not yet regarded as a major pest of cocoa. It has been a serious pest of bookbindings since the first discovery of the species in books imported from Ceylon in 1924.

44. The beetle lays its eggs in crevices in sacks and beans, the larvae boring into the cotyledons and eating out about one half of a complete bean. In contrast to *Ephestia* and *Araecerus*, *Lasioderma* is able to attack sound dry beans. The larvae pupates within the bean, and the adult makes a characteristic exit hole. Counting of exit holes, however, seriously underestimates the degree of infestation by *Lasioderma*. The beetles fly at dusk, and consequently spread rapidly from store to store. This habit has been extensively exploited in trapping with adhesive traps.

Araecerus fasciculatus (de G.)

WEST AFRICAN COCOA WEEVIL

45. The status of *Araecerus* as a cocoa pest in Nigeria and the Gold Coast has completely altered in the last twenty years owing to the more careful attention which has been paid to the preparation of the crop. Infestation by *Araecerus* originates on the drying trays, but may develop in stores where the cocoa has taken up moisture. Adults are thus most commonly seen in stocks of ungraded cocoa.

46. Prior to egg laying, the female beetle pierces the testa repeatedly and each hole is sufficiently large to permit the entry of the young larvae of a more serious pest, *Ephestia cautella*. The development of the larvae of *Araecerus* is profoundly influenced by moisture content, which is optimal at about 12—15 per cent. and which is found nowadays only on the drying trays and in inferior parcels of beans offered for sale at merchants' stores. Cocoa which has been dried to a reasonable commercial standard of 8 per cent. moisture content is safe from attack by this species.

Necrobia rufipes (de G.)

THE COPRA BEETLE

47. Primarily a pest of palm kernels in Nigeria, and of copra in the Gold Coast, *Necrobia* spreads rapidly in cargoes in transit, and appears at first sight to be more of a menace than it is in fact. Actual damage to palm kernels is negligible, and the impression has been gained that the species is chiefly predaceous on other infesting insects, or may even be a feeder on moulds. It is, however, an important index of conditions favouring cross infestation. The status of this insect is certainly a subject for future investigation.

INSECTS DAMAGING GROUNDNUTS

48. The damage done by insects to West African groundnuts is serious, and is shown both by loss of weight and fall in quality as reflected by an increase in free fatty acid content of the oil.

49. The following are the major infesting insects: —

Tribolium castaneum (Hbst.)	The Red Rust Flour Beetle, or "Groundnut Bug".
Trogoderma granarium Everts.	Khapra Beetle.
Caryedon fuscus (Goetz).	Groundnut Bruchid.
Ephestia cautella (Wlk.).	Fig Moth.
Plodia interpunctella (Hbn.).	The Indian Meal Moth.
Corcyra cephalonica (Stt.).	Rice Moth.

The list of the more important insects found in groundnuts during the Survey is given in the Appendix.

Tribolium castaneum (Hbst.)

THE FLOUR BEETLE

50. Universally abundant in all storage installations, *Tribolium* is a primary pest of shelled groundnuts, and can attack the unbroken nut. The species also attacks cereal food crops such as guinea corn and *Pennisetum* millet, and the generations follow each other every six-seven weeks. Most of the damage is caused by the adult beetles which are long lived. They eat their own eggs and larvae to such an extent that relatively few of the immature stages are seen.

Dusk flights and peripheral stack infestation are typical of *Tribolium* just as they are of *Ephestia* (Para. 40).

51. *Tribolium* is living near to the lower limit of its humidity tolerance at Kano, and a delicate seasonal equilibrium exists with the more drought-resistant *Trogoderma*. At the ports in the more equable humid conditions *Tribolium* spreads rapidly to other produce, but appears to do no damage to cocoa or palm kernels.

Trogoderma granarium Everts

THE KHAPRA BEETLE

52. A remarkable *Trogoderma* outbreak of explosive suddenness occurred at Kano in January, 1949, although the species had not been found in any of the storage premises previously examined by the Survey in the course of the research programme. *Trogoderma* had never been reported from Nigeria. In attempting to trace the origin of this outbreak, it was subsequently discovered that *Trogoderma* had been present in Kano for at least two years and that cargoes from Nigeria containing *Trogoderma* had been reaching the United Kingdom during this period.

53. The damage to groundnut is caused solely by the larvae (Fig. 9). The adult is short-lived and does not feed. The generations follow regularly every six weeks or so, and are marked by eruptions of the full grown larvae. Moving in large numbers at dusk, the larvae weaken the fibres of the bags and bursting occurs, which is quite typical of *Trogoderma* attack.

54. The eggs are laid amongst the nuts and the larvae move freely within the stack so that damage is not typically confined to the peripheral bags. Furthermore, the cryptic habit of the larvae, and the fact that the adult is flightless, renders the detection of light infestations almost impossible.

55. *Trogoderma*, as in other parts of the world, thrives in the hot, dry climate of Northern Nigeria, and tends to replace species such as *Tribolium* under Northern Nigerian conditions, when prolonged storage is necessary.

56. It is important to note that *Trogoderma* has not so far spread at the ports to other products, and it appears unable to attack cocoa or palm kernels.

Carydon fuscus (Goety)

THE GROUNDNUT BRUCHID

57. This Bruchid is the major pest of groundnuts in the shell, and in Nigeria is mainly confined to seed groundnuts. It has been found during the present survey attacking shelled groundnuts stored in bulk. In Senegal and the Gambia, where groundnuts are marketed and shipped in the shell, *Caryedon* causes serious losses to the export crop as well as to seed. This is accentuated when storage is necessary after the rains begin in May. Work on the biology of this beetle has been done by Corby in Nigeria.*

MOTH INFESTATION OF GROUNDNUTS

58. Infestation by the three species of moths is generally overshadowed by that due to beetles, but in under-cover storage, large numbers of flying moths can always be found. *Ephestia cautella* alone is a source of danger to other commodities; *Plodia interpunctella* is generally more numerous in the early part of the season, but does not seem to spread to other products in transit. *Corcyra cephalonica* only develops after prolonged storage.

CONDITIONS FAVOURING INSECT INFESTATION

59. Insect infestation results from a combination of geographical and physical factors. We have found that the following favour infestation: —

(A) At any or all the storage points already enumerated: the retention of produce for prolonged periods during which physical conditions favourable to insect increase may develop; a few insects picked up in farmers' stores may build up heavy infestation within a few months.

(B) At all points: faulty preparation of the produce, and storage at high humidities may result in breakage, high moisture content or other defects which lead to enhanced susceptibility to attack.

(C) En route: the practice of mixing produce from different sources leads to the spread of infestation, and low standards of hygiene in storage and transport favour cross infestation from other products.

(D) The use of second-hand bags without prior cleansing and disinfestation is a most important factor.

PROLONGED STORAGE

60. Regarding (A) above, it has not proved possible to make an extensive survey of small farmers' or middlemen's stores. From past experience in the Gold Coast and elsewhere, it cannot be doubted that if storage is to be prolonged at subsequent stages (six months or more), no amount of treatment external to the bags will guarantee that severe outbreaks will not develop from small but practically undetectable infestations from the primary sources. This mode of infestation is particularly applicable to the cocoa crop.

61. Much greater and more acute dangers are resident in up-country groundnut centres, such as Kano, and in those cocoa centres, such as Ondo, which serve creek ports. Here, prolonged storage is frequent, and *Tribolium*, *Trogoderma*, *Ephestia* and *Lasioderma* are endemic and well entrenched in storage sites. The need for progressive disinfestation of such sites by hygiene and chemical measures should be self-evident, and has formed an important part of the work of the Survey. The extension of such work into the bush towards the small farmer is a long term measure which bristles with practical difficulties, but which should not be neglected in the future.

* Unpublished report of the Agricultural Department.

62. The principal example of prolonged storage as a source of infestation, has been the delay in railing of the Northern Nigerian groundnut crop caused by rolling stock difficulties. Figures of the crop carried over from year to year since 1946 are as follows: —

November	1946	5,000 tons
	1947	92,252 „
	1948	155,420 „
	1949	137,556 „
	1950	Nil.

The figure for 1950 reflects both improvement in railings and a drop in crop from the average of 300,000 tons to about 180,000 tons.

It was this retention of stocks which resulted in the build-up of *Tribolium* and *Trogoderma* populations at Kano to proportions which demanded urgent and wholesale control measures.

Similar but less dramatic hold-ups occur annually on the rivers which are only seasonally navigable. All export products are liable to be affected in this way. In times of shipping or lighterage shortage, delays at buffer storage points have undoubtedly contributed largely to the increasing importance of *Lasioderma* in cocoa.

FAULTY PREPARATION

63. In regard to paragraph 59 (B) above, it may be stated generally that produce which is insect-free and which is stored in proper buildings in which modern chemical protection can be given, cannot be regarded as a source of infestation. Such conditions are far from being realised in practice, and the Survey has paid special attention to infestation caused by bad preparation of the crop and poor storage with exposure to seasonal climates.

COCOA BEANS

Faulty preparation of the beans is attributed to a number of factors: —

(*a*) Small producers preparing only small heaps cannot ensure even fermentation, and this results in undue germination of beans.

(*b*) Rough handling of beans in transit and during grading results in broken testae, already noted as a potent source of *Ephestia* attack.

(*c*) Incomplete drying, especially in the wet season, enables *Araecerus* which is primarily a field pest, to develop on the drying trays and in subsequent storage. Even more important as a source of downgrading of cocoa is the growth of moulds owing to this cause.

The effect of these factors on cocoa infestation generally is that early *Araecerus* attack paves the way for *Ephestia*, which otherwise lives on the remnants of mucilage, etc. *Lasioderma* on the other hand does not appear to be deterred by even the best preparation and can infest good sound dry beans.

64. Cocoa is a hygroscopic product, but in Nigerian conditions there should be no great increase in moisture content during normal storage periods since most of the main crop will already have been shipped by April, i.e., before the seasonal rise in humidity takes place. The light (wet season) crop must be regarded as the chief danger, as it is often stored for longer periods at higher humidities and is liable to be mixed in with the standard crop at a later date.

For marketing purposes, cocoa of up to 8 per cent. moisture content is regarded as commercially dry. An experiment at Lagos yielded the following typical figures for the changes in moisture content over a period of 6 months (see Table I).

The observed downgrading was caused by an increase in insect damage and in mouldy beans. The relative importance of these two factors is difficult to

determine. Theoretically, at 8 per cent. mould should not develop, but, in practice, association with damage by insects appears to favour mouldiness. Furthermore, we are not satisfied that existing methods of sampling are capable, in practice, of giving a true indication of the physical condition of a complete parcel of cocoa. In particular the early stages of insects within the beans will almost certainly be missed during grading.

TABLE I

MOISTURE CONTENT CHANGES OF COCOA STORED IN LAGOS

Month	Mean m/c	Mean Ambient R/H% (9 a.m.)	Mean Temp.	Grade
1	6·25	72	27·0	I
2	6·46	80	27·8	I
3	6·80	84	29·0	II
4	8·23	87	29·0	II
6	7·28	84	27·0	Below grade

GROUNDNUTS

65. The only preparation of the crop consists of drying and shelling. The arid conditions at harvest, and the prohibition of marketing during the usual drying period of about three weeks are in general sufficient to guarantee that nuts will contain not more than 3 per cent. of moisture.

Shelling is always done by pounding the nuts with a heavy stick, in a hollowed-out tree trunk, or a large gourd. The resulting breakage, which is in the region of 66 per cent., does not in our experience materially enhance susceptibility to insect attack. The whole groundnut, even when protected by the testa, does not present an insuperable barrier to *Tribolium,* nor to the other insect species. The influence of breakage on free fatty acid content is a separate question which is considered later (Para. 78), when total losses are to be assessed.

66. As with cocoa, the months following the harvest of groundnuts (November —April), are climatically the best for storage in Northern Nigeria (See Fig 2). If storage is prolonged beyond April, as in recent years in Kano, the moisture content of groundnuts rises with the humidity. Experimental data are summarised below.

TABLE II

MOISTURE CONTENT PER CENT. DURING THE YEAR OF GROUNDNUTS STORED IN KANO

Month	Experiment in lab. outhouse (mean)	Commercial stacks (Range)
January	3·4	2·3—3·3
February	3·3	3·1
March	3·0	3·2
April	3·0	3·8
May	3·8	2·8—4·5
June	4·1	3·0—4·2
July	4·8	3·4—5·3
August	6·0	3·5—6·3
September	5·9	3·4—6·1
October	4·6	3·0—4·9
November	3·5	2·9—4·3
December	3·4	2·5—5·5

Since it is well known that humidities of 75-80 per cent. are optimal for most storage insects, the restriction of storage of export produce to the dry season will normally reduce insect losses to a minimum. *Trogoderma,* however, is an exception to this rule, and a temperature of 35° to 40° C., at almost any humidity, can be regarded as optimal. Thus the exposure of the pyramid stacks to high temperatures will discourage *Tribolium* but will not interfere greatly with the development of *Trogoderma* populations. Experimental results based on therm-couple ropes built into certain pyramids and warehouse stacks are given below.

TABLE III

TEMPERATURES (°C.) RECORDED WITHIN STACKS OF STORED GROUNDNUTS

Trogoderma infested Pyramid			Trogoderma infested Warehouse			Trogoderma free Warehouse		
Date	Surface bags	Centre	Date	Surface bags	Centre	Date	Surface bags	Centre
May	43·2	40·6	May	33·3	43·1	May	38·1	41·5
July	40·7	42·2	Sept.	32·8	41·2	Sept.	31·7	40·1
Sept.	43·5	45·6	Jan.	26·3	42·7	Feb.	25·4	27·5
Oct.	42·5	45·8						

High *Trogoderma* populations tend to maintain these high temperatures in the interior of stacks, but *Tribolium* cannot survive at such levels.

HYGIENE PRACTICES

67. The problem of the mixing of small parcels of all tropical produce (cocoa, palm kernels, groundnuts) for marketing referred to in paragraph 59 (C) looms large in Nigeria. By this means the spread of original infestations over wide areas is guaranteed. The deliberate mixing of old stocks and inferior produce with the current crop is a persistent source of insect infestation.

68. Storage hygiene routine consists in sweeping and white-washing of empty stores both in cocoa and groundnut areas. The effects of such a routine even when conscientiously carried out are often nullified by cross infestation. The practices of stacking cocoa and palm kernels in adjacent premises, and old and new crop groundnuts in adjacent pyramids ensure immediate infestation, which, in the absence of chemical protection, builds up rapidly.

Whilst we do not in any way belittle storage hygiene, its usefulness is obviously bound up inextricably with administrative and chemical control measures.

THE USE OF SECOND-HAND BAGS

69. Regarding paragraph 59 (D). In normal times all produce is exported in bags, but recently groundnuts have been "skipped" into ships' holds, the bags being repaired and returned into general use without disinfestation. The dangers of such a practice are considerable, since *Ephestia* is commonly carried from Kano on groundnuts to cocoa and palm kernel areas. This practice was brought to the attention of the Survey by the Department of Marketing and Exports, and a fumigation technique has been developed which should obviate danger from this source in the future.

70. A further danger of unknown extent is presented by the service bags used for the initial transport from the producer. These bags are never cleaned and are in continuous use for produce for export or consumption. Guinea corn is probably the original source of infestation of export groundnuts by *Trogoderma* and *Tribolium*.

ESTIMATION OF LOSSES IN COCOA BEANS AND GROUNDNUTS

71. It is always a matter of difficulty to establish actual losses of produce caused by insect infestation. There are two well-marked aspects.

(A) Loss of weight.

(B) Loss of quality.

Loss of weight is typical of infested groundnuts but is frequently masked by an equivalent uptake of moisture.

Loss of quality is the exclusive criterion in cocoa, but it has hitherto been difficult to pin-point the causes. The general tropical problem of a low standard of acceptance of produce by buyers or consumers does not exist with cocoa, in which the standard laid down by the West African Governments leaves little room for improvement. In groundnuts, the reverse is true, and the small admitted weight losses bear little relation to the actual destruction of food oils by insect infestation.

LOSSES TO COCOA IN STORAGE

72. Since weight losses in cocoa are negligible, estimates of losses attributable to insects can only be based on tonnage downgraded prior to shipment; the downgrading may also be caused by other progressive defects such as mould. Samples are taken by Produce Examiners from the bulked cocoa at buying centres. Random handfuls of cocoa beans are mixed, and a final sample of 20 ounces obtained. From this sample, 300 beans are counted, germinated beans separated, and the remainder are sliced for examination. The sample is then classified as follows:

(*a*) Fully fermented.
(*b*) Slatey (unfermented).
(*c*) Flat (immature).
(*d*) Mouldy.
(*e*) Mouldy and "weevilly" (any insect damage).
(*f*) Weevilly.

A similar procedure is adopted separately for germinated beans.

On the basis of this examination, the cocoa is placed into one of the following grades:

TABLE OF COCOA GRADING

Grade	Total Defective	Mouldy	Slatey
I	Less than 5%	None	Less than 5%
II	Less than 10%	Less than 5%	Less than 10%
III	Less than 10%	Less than 5%	Less than 20%
"No grade"		Exceeding these limits.	

N.B.—The term "defective" includes broken, misshapen, weevilly and germinated beans.

73. As a check on deterioration, cocoa is periodically regraded in store and transit from spear samples. The sampling spear removes about 500 beans, samples being mixed and examined as at buying centres. In principle, every tenth bag should be sampled. It will be clear from the defects listed above, that only items d, e, and f, concerning mould and insect damage can increase during storage.

Downgrading figures for cocoa in transit storage between primary grading up-country and shipment are not inconsiderable. The official figures of the Department of Marketing and Exports for 1948-49 were 1.3 per cent. of the

FIG. 5. *Typical West African merchant's store in Kano.*

FIG. 6. *Pyramid under construction showing plinth.*

FIG. 7. *Typical groundnut pyramids.*

FIG. 8. *Covered pyramid showing arrangement of rick sheets.*

FIG. 9. *Typical* TROGODERMA *damage showing burst bags.*

FIG. 10. *Spraying a pyramid with an aqueous suspension of insecticide at Kano using a Lister SS2 machine. (Note operator is too close to pyramid.)*

FIG. 11. *One of the Native Authority storage sheds at Kano which was used for fumigation.*

FIG. 12. *Arrangement of cylinders and pipes for applying methyl bromide to fumigation chambers.*

total crop. This apparently small figure comes into better perspective when it is considered that these losses would be preventable if proper storage techniques were to be applied.

74. The Survey has not found it possible to differentiate losses caused by insects and mould, but it is considered that insects play an important part. In order to illustrate the potential increase in insect infestation during storage, the following figures were obtained in the Gold Coast. Monthly counts were made of insect damage on random samples of beans harvested over the main crop season.

TABLE IV

INCREASE IN PERCENTAGE OF INSECT DAMAGE IN 1946—1947 IN THE GOLD COAST

Storage Period (months)	Up-country Stores				Port Stores			
	Grading Date				Grading Date			
	Oct.	Nov.	Dec.	Jan.	Oct.	Nov.	Dec.	Jan.
1	0·5	0·2	0·7	1·2	0·3	0·6	1·1	1·5
2	1·3	1·0	1·1	2·3	1·2	1·4	3·1	3·5
3	2·1	1·5	2·5	2·9	2·8	3·8	4·1	3·7
4	2·5	2·6	2·8	3·3	4·1	4·9	4·2	4·4
5	2·8	3·2	3·5	5·5	3·4	4·3	4·6	5·8
6	3·0	3·4	4·8	5·8	4·8	5·1	5·2	7·1

The increases were caused mainly by *Ephestia cautella* and to a lesser extent by *Araecerus*.

LOSSES TO GROUNDNUTS IN STORAGE

75. (i) *Weight losses.* Weight loss is considerable and may amount to 5 per cent. during a period of 12 months storage up-country. This figure was obtained as a result of a number of experiments carried out by exposing weighed bags to insect attack in commercial stores and pyramids. All weight measures are complicated by the changes of moisture content during storage (see also Table II), and the experimental results quoted here are corrected for this factor. The actual weight losses are incurred by the conversion of part of the nut into dust, carbon dioxide and water, by the feeding of the insects. In commercial practice it is important to note that the dust is retained in the bags, and does not appear as a loss. In the experiments the dust was sieved out and its weight added to the measured loss of weight.

76. When *Trogoderma* was present, the weight losses were materially increased, as shown by the following table: —

TABLE V

PERCENTAGE LOSS OF DRY WEIGHT CAUSED BY INSECTS DURING NORMAL STORAGE OF 9—12 MONTHS

	Pyramids		Warehouses	
	Inside bags	Outside bags	Inside bags	Outside bags
Trogoderma present ...	2%	6½%	5¼%	7%
Trogoderma absent ...	2%	3½%	2½%	4½%

Routine determinations of the dust content of bags before railment gave commensurate figures supporting the suggestion that this loss was caused by insect infestation. For six warehouses, percentages were 4.75, 5.1, 4.1, 3.1, 4.8 and 5.1.

The officially admitted loss in weight of 0.1 per cent. is the resultant of the insect loss of 5 per cent. balanced by a moisture uptake in storage and transit (estimated 2 per cent.) together with the weight of dust shipped (3 per cent.).

77. (ii) *Quality losses.* Direct damage by moisture, chiefly occurring in the bottom layers of sacks in both warehouses and pyramids is officially stated to be 0.25 per cent. The nuts are caked, blackened and rotten. This damage can usually be prevented by the use of dunnage.

78. The more serious general effect of moist conditions is to increase the free fatty acid content (F.F.A.) of the oil, which forms 50 per cent. of the dry weight of the nut. This effect is also produced by a number of other factors, the chief of which are breakage and insect damage.

The F.F.A. of nuts at harvest is 0.5 per cent. or lower, but after a period of 12 months in a typical Kano warehouse, the following figures were obtained: —

Whole Nuts ...	...	4 per cent.
Split or half nuts	...	9 per cent.
Broken Nuts ...	...	17 per cent.
Dust ...	...	70 per cent.

The oil content of dust is only 17 per cent. The progress of F.F.A. formation is shown graphically in Fig. 13.

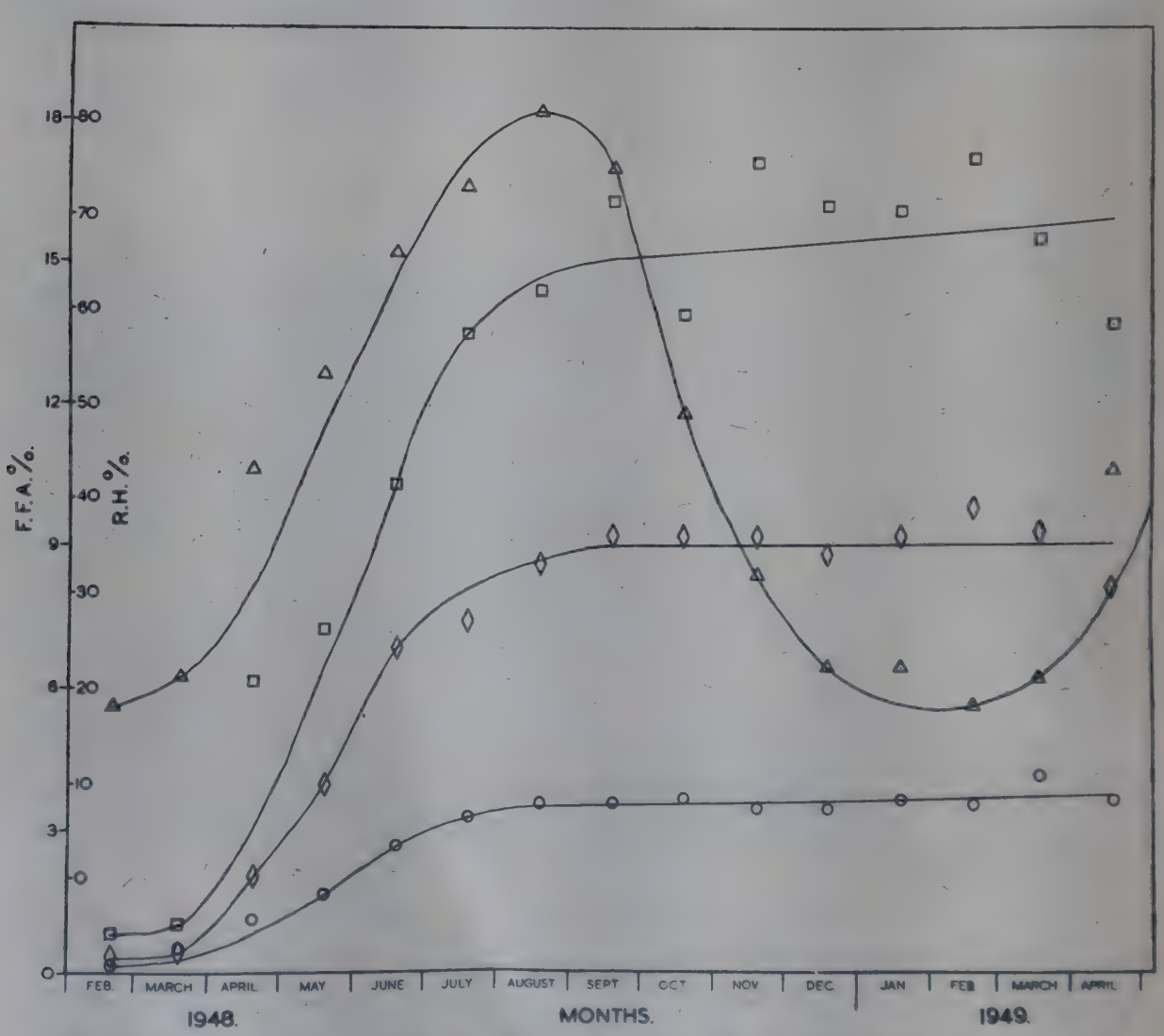

FIG. 13. *Curves showing the change in the FFA of samples, divided into whole, split and fragmented nuts and in the moisture content of complete samples taken monthly from the outside bags of a commercial stack stored in the warehouse shown in Fig. 5.*

□ *Fragmented* ○ *Whole* ◊ *Splits* Δ *Moisture content.*

79. Insects accelerate free fatty acid formation by increasing the surface area of nuts, breaking cells or by introducing enzymes or moulds. It is impossible in the field to determine how far insects are responsible for the observed rise in F.F.A. A laboratory experiment was therefore set up to ascertain the rise in F.F.A. of a series of 50 gm. samples when exposed to attack by 200 adult *Tribolium*. The results are presented in Table VI.

TABLE VI

PERCENTAGE OF F.F.A. IN GROUNDNUTS AFTER ONE YEAR STORAGE IN TRIBOLIUM EXPERIMENT

	Whole Nuts	Half and Broken Nuts
Tribolium present	3·8%	13·4%
Tribolium absent	2·5%	3·1%

This experiment indicates that an F.F.A. value of 3 per cent. should not be exceeded in a year's storage in Northern Nigeria. Any value in excess of this can reasonably be attributed to insect attack.

Regular determinations by the Survey of the F.F.A. of groundnuts leaving Kano show an average value of 5.4 per cent., which rises during shipment and averages 6.4 per cent. on arrival at the processing mill in the United Kingdom.

80. Since the loss of edible oil is approximately double that of the F.F.A. value, an increase of 6 per cent. in F.F.A. between harvest and processing means a total loss of 12 per cent. in food oils. In addition, the presence of dust in nuts for processing imparts a dark colour and a bitter flavour to the oil and impairs its keeping quality.

81. The losses enumerated above are real food losses which are, in our opinion, largely preventable but which are only too often ignored, as the acid oil can easily be diverted to soap manufacture.

82. Ancillary losses from burst bags occur in other cases of high *Trogoderma* infestation or water damage (Fig. 9). In a typical year it is estimated that 170,000 bags were lost by water damage and 80,000 bags by *Trogoderma* damage, together forming nearly 10 per cent. of the total number used.

CONTROL MEASURES

83. Experimental and large scale trials were made with a number of insecticides. Although the measures reported here are all chemical, it must be stressed that their practical and economic efficiency depends on the simultaneous adoption of our recommendations on hygiene in stores.

The results of these trials have indicated three main lines of attack.

(*a*) Spraying of empty premises or stacks of bagged produce with aqueous suspensions of D.D.T. or B.H.C. for immediate kill and residual effect.

(*b*) Fumigation, especially with methyl bromide, to control infestations already well established. Future extension to all suspect produce arriving at central storage.

(*c*) Disinfestation of second-hand bags.

The following measures were tested under restricted conditions only because there appeared to be some practical limitation to their general use:

(*d*) Spraying of empty premises with oil solutions of D.D.T., B.H.C. and pyrethrins.

(*e*) Admixture of the produce prior to storage with inert or insecticidal dusts.

(*f*) The use of smoke generators in full or empty stores and railway wagons.

(*g*) The use of the Todd Insecticidal Fog Applicator.

(*h*) Trapping of insects by "Ate" strands (Golding, 1941) soap solutions, etc.

(*i*) Impregnation of sacks with D.D.T.

SPRAYING

84. Application trials have been carried out using:

(i) An "Eclipse" stirrup pump type of sprayer.

(ii) A Lister S.S.2 power sprayer of the orchard type, with adapted nozzles recommended by Kearns (Fig. 10).

(iii) The Todd Insecticidal Fog Applicator (T.I.F.A.).

85. The Eclipse sprayer, or a hand operated sprayer of a similar type, is practical for use in stores of moderate capacity (under 500 tons), or for use by the individual small storage merchant should the necessity of applying treatment become his responsibility.

86. For large-scale work the Lister S.S.2 power machine in capable hands is by far the most useful machine. It needs little attention, is cheap to run, and can be manhandled into all types of storage premises. The African operator, however, is inclined to stand too close to the stack whilst spraying, causing an excessive run-off which must be avoided in premises which may be used for grading. Contamination of produce with insecticides must not be risked.

87. Treatment of store fabric with aqueous suspensions can either supersede the present routine measure of lime washing prior to the opening of marketing, or such suspensions can be applied over limewash, provided that an interval between applications is allowed to elapse. The latter is to be preferred on account of the psychological effect of lime washing which has done so much in the past to ensure that premises are properly cleaned at least once a year. The results of a typical spraying experiment were as follows:

TABLE VII

MORTALITY OF 50 ADULT TRIBOLIUM ON D.D.T. TREATED WALLS IN LAGOS

(2 hours exposure)

Dosage	% Dead		Age of D.D.T. Film at Exposure
	Treated	Control	
50 mg/sq. ft.	100	49	32 weeks
100 ,, ...	94	10	32 ,,
150 ,, ...	100	6	32 ,,
200 ,, ...	96	18	24 ,,
200 ,, ...	100	6	24 ,,

Wall spraying at rates of 50 and over 100 mg/sq. ft. against heavy infestations of *Lasioderma* in cocoa stores was carried out on an extensive scale in September/October, 1949. Although figures of mortality were not available at the end of the Survey, there is no doubt as to the efficacy of the measure.

88. In Kano much higher dosages of D.D.T. were found to be necessary, since the principal pest, Tribolium, was present in such numbers that new invasions occurred nightly. The practical dosage proved to be between 300—400 mg/sq. ft. The effect on the appearance of stores so treated was so obvious as to render numerical estimation superfluous.

89. For *Trogoderma* infestations, even the high dosages were comparatively ineffective, as the following Table indicates.

TABLE VIII

INCIDENCE OF TROGODERMA IN WAREHOUSES AND PYRAMIDS AT KANO SPRAYED WITH AQUEOUS SUSPENSIONS OF D.D.T. AND B.H.C.

Treatment	No. of Warehouses	*Trogoderma* Infest.			No. of pyramids	*Trogoderma* Infest.		
		Absent	Light	Heavy		Absent	Light	Heavy
D.D.T. less than 300 mg/sq. ft. ...	21	5	13	3	46	15	24	7
D.D.T. over 300 mg/sq. ft. ...	11	6	5	0	64	24	25	15
B.H.C., D.D.T. mixed* ...	6	1	2	3	35	9	18	8
Control	39	15	13	11	13	2	6	5

*These Warehouses were heavily infested with *Trogoderma* at the time of spraying.

Although it had been suggested that B.H.C. was more effective against *Trogoderma* than D.D.T., neither of these insecticides gave any significant control, either in water suspension or oil solution. The addition of pyrethrum did not affect this result.

90. The application of aqueous sprays directly to bagged produce is limited by the danger of sorption, taint, and in certain areas, the increase of moisture content.

91. In cocoa, an experiment by K. G. Smith showed that even a dosage of 1,000 mg/sq. ft. on bagged cocoa was insufficient to prevent infestation by *Ephestia* developing when individual bags were exposed to insect attack in a warehouse. *Tribolium* however, was successfully controlled.

92. In groundnuts at Kano, bag spraying was limited to pyramids which were treated at the earliest moment after completion. The dose of 300 mg/sq. ft. of D.D.T. was applied with the Lister machine at the rate of 40 gallons of spray fluid to each 750 ton pyramid. As in store spraying, the practical success of the operation was easily observable with *Tribolium*, but *Trogoderma* proved to be highly resistant to this treatment.

FUMIGATION

93. Fumigation of stored produce had hitherto been employed in Nigeria only for food stacks infested by weevils. The fumigant used was Ethylene Dichloride/Carbon Tetrachloride (3:1) mixture, and provided that dosages of 2 to 3 gallons per 1,000 cu. ft. of storage space were allowed, adequate control even of *Trogoderma* was generally secured, after minimum periods of 36—48 hours.

FUMIGATION OF GROUNDNUTS

94. The emergency caused by the sudden appearance of *Trogoderma* in the Kano groundnut stocks led to the introduction of methyl bromide. Large-scale fumigation of groundnuts was first instituted in Kano in February, 1949. Methyl bromide was selected as the fumigant because of its excellent penetrative powers and subsequent rapid airing, which permit of solid stacking.

95. Routine fumigation, involving over 70,000 tons in the first year, was done in warehouses built of stone with corrugated iron roofs, and each of 150 tons capacity (Fig. 11). The eaves had been sealed as well as possible with concrete, but the stores could not in any way be considered gas-tight. Subsequent recommendations by Mr. L. Peverett of the London Fumigation Company should go far to overcome the inherent defects of these fumigation chambers, for such they were originally designed to be.

96. Groundnuts for fumigation were moved from merchant's stores $\frac{3}{4}$ to 3 miles distant by road, in open lorries. Methyl bromide was piped from cylinders over the closely stacked nuts at the rate of 30 lbs. per 150 ton lot (Fig. 12). After 24 hours, during which time concentration (mg. per litre) × time (hours) = C × T products of 50-60 were reached in the air space between the bags (Fig. 14), the stores were aired for a further 24 hours. The nuts were then loaded into railway wagons for transport to the coast, 700 miles distant.*

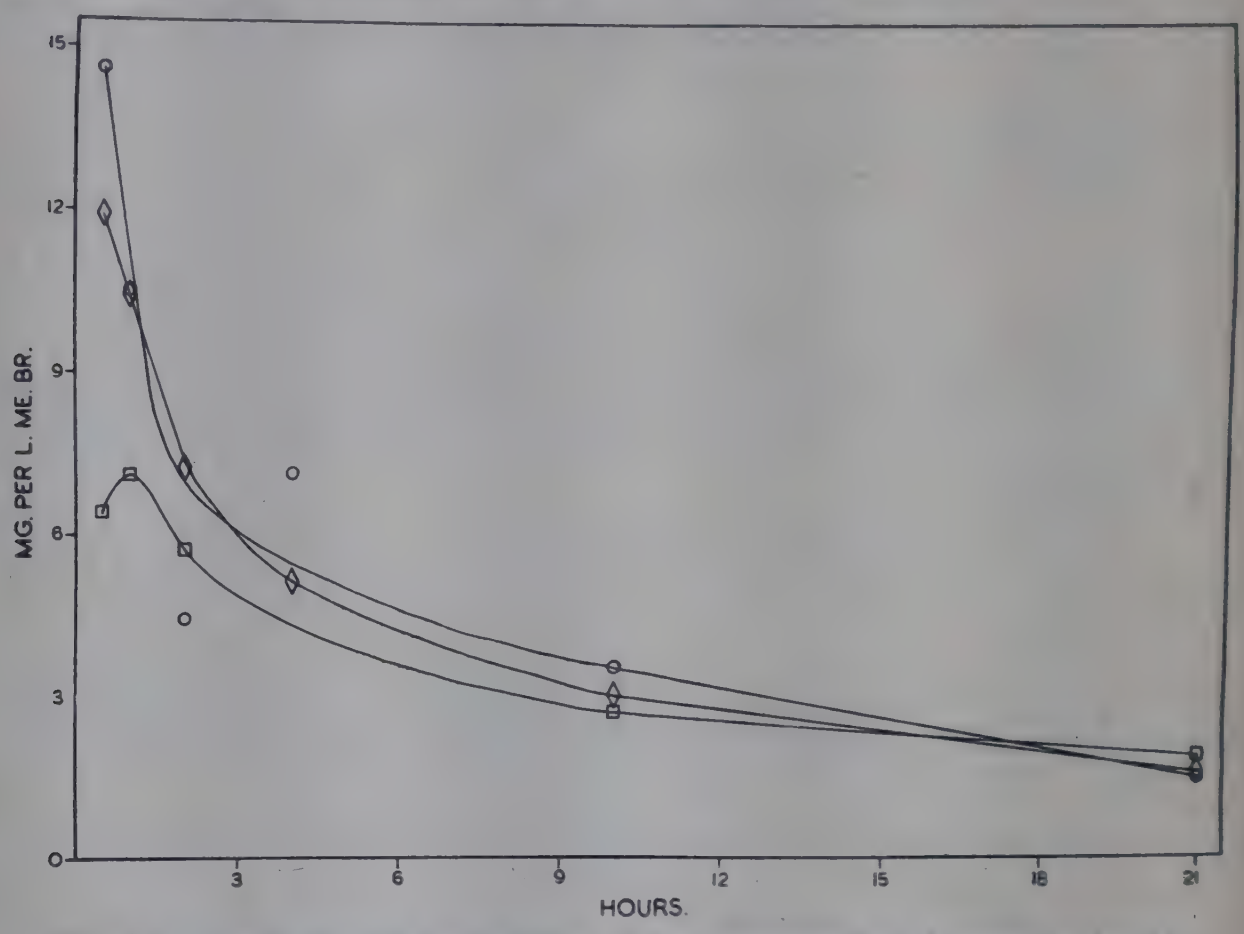

FIG. 14. *Curves showing concentration of gas maintained in fumigation chamber after making good of defects caused by the climate. The gas was applied through atomising jets at middle of free space above stack.*

○ *Top layer of bags middle of store.*

◊ *Bottom layer of bags middle of store.*

□ *Bottom layer of bags near door of store.*

DECANTATION OF METHYL BROMIDE

At this point, it is convenient to deal with the important problem of decanting methyl bromide, a poisonous volatile liquid—from bulk cylinders of 1,800 lbs. weighing $1\frac{1}{2}$ tons, into 180 lb. service cylinders from which individual fumigations were done. A suitable petrol-driven compressor was installed at the port

* It should be emphasized that the fumigants mentioned in this report—ethylene dichloride, carbon tetrachloride, carbon bisulphide and methyl bromide—both in the liquid and gaseous state are highly toxic to man and precautions must be taken in their use to ensure that these liquids do not come into contact with the bare skin and that the volatile products are not inhaled. Carbon bisulphide vapour is inflammable and care should be taken to see that whilst it is being applied and during the entire period of fumigation no naked flame, match or burning cigarette is brought into the building.

of Lagos. The two cylinders were connected and the required weight of liquid blown under a pressure of 75 lbs./sq. inch, into the smaller cylinder. Some difficulties were encountered in the shape of air locks, engine troubles, and corrosion of metal fittings of the large cylinder in transit, but these were eventually overcome. In general, decanting is quite practicable for use in tropical conditions. The poison danger should not arise provided that a mask is worn by the operator manipulating the pipes. Even the momentary splashing of the hands with methyl bromide should not cause blistering under local conditions, provided that the hands are dipped in water immediately.

FUMIGATION OF BAGS IN PYRAMIDS

97. Pyramid fumigations were done experimentally, on 1,000 tons only, by the use of R.A.F. rubber dinghy sheets sealed together with cocoon plastic. Methyl bromide was led into the top of the pyramid by copper piping. Atomising jets were employed to spray the liquid into a small chamber made by removing a few of the top bags. This method was introduced and supervised by Mr. L. Peverett during his visit.

Owing to the better circulation and absence of dead space under the sheets, C × T products of 200 mg/hrs per litre were easily obtained with a dosage of 180 lbs. of fumigant for a commercial 750-ton pyramid. (Fig. 15.)

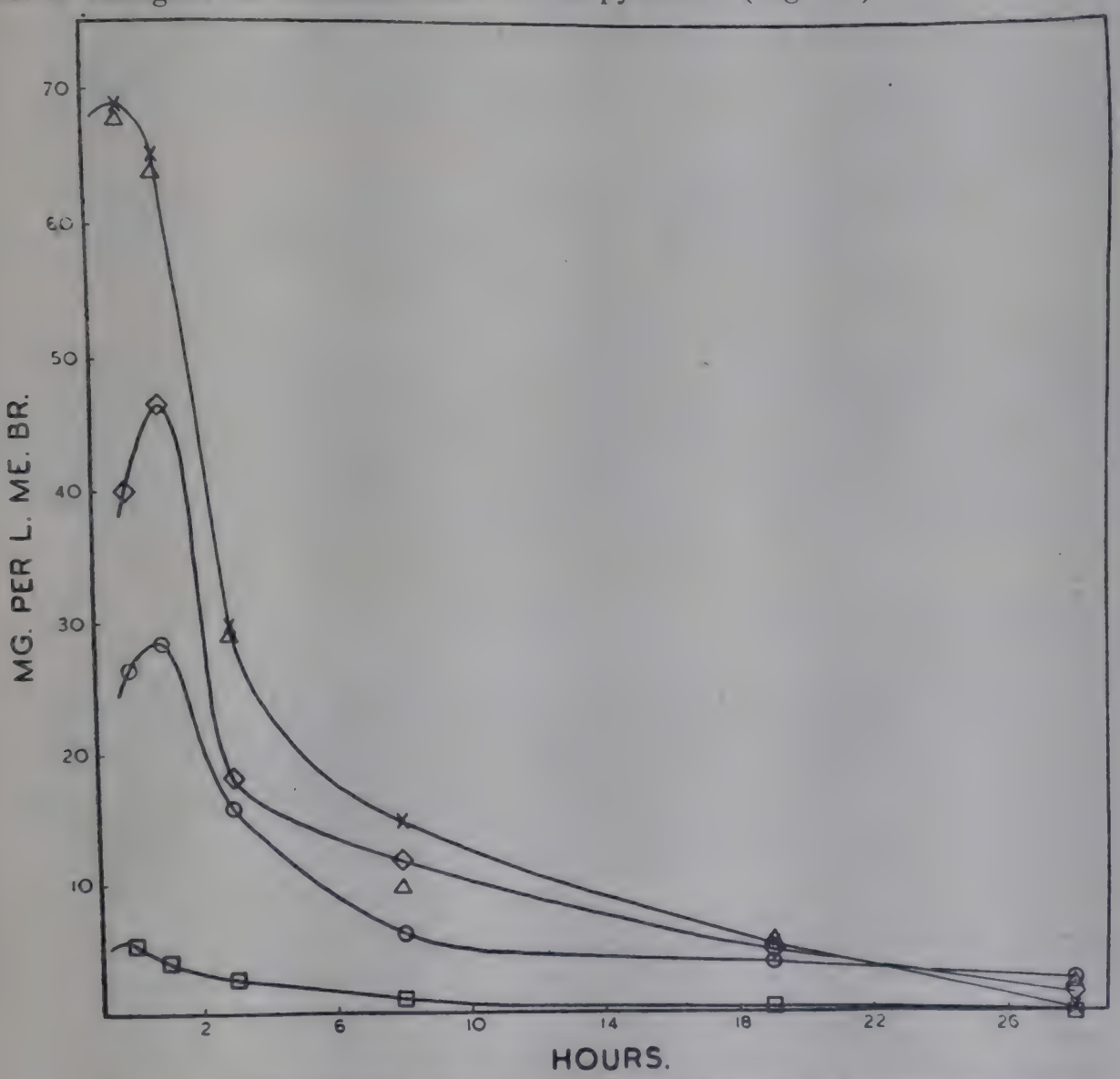

FIG. 15. *Curves showing concentration of gas maintained in commercial pyramid fumigated under dinghy sheeting. The gas was applied through atomising jets at the top of the pyramid.*

× *Inside top bag.* ○ *Inside middle bag.* △ *Top free space.* ◊ *Bottom free space.* □ *Sampling pipe blocked.*

The perfect initial control of all infesting insects, combined with the absence of double handling, points to this method as the most economic and efficient treatment, where fumigation is appropriate.

98. Fumigation of produce in sealed railway wagons, also investigated by Mr. Peverett, would appear scientifically feasible, but administrative objections, such as delay in turn-round of wagons, and the risks of poison during transit, have so far proved insuperable.

99. The efficiency of fumigation, as judged by the inspection of produce after treatment, was excellent for the first 6 months. After the Unit ceased to have direct control of fumigation, however, examinations of shipments in the United Kingdom carried out by the Infestation Control Division of the Ministry of Agriculture showed that an increase in infestation had occurred. Results of these examinations kindly furnished by the Infestation Control Division are shown in Table IX.

TABLE IX

INFESTATION CONTROL DIVISION RECORDS OF TROGODERMA IN GROUNDNUTS FROM WEST AFRICA

Place of Shipment	Period	Ships Inspected	Ships Infested	Control of *Trogoderma*
Leaving Nigeria ...	Up to Jan. 1949 ...	—	31	—
,, ,, ...	Jan./Mar. 1949	8	6	Starting
,, ,, ...	Apr./May 1949	9	1	Effective
,, ,, ...	July/Oct. 1949	38	18	Deteriorating
,, ,, ...	Oct. 1949 to Oct. 1950 ...	107	57	Poor

The large number of infested shipments may be ascribed by two factors, the necessity of shipping unfumigated nuts, and the rapid deterioration of the fumigation stores, caused by expansion and warping of the metal roof. On the other hand we are strongly of the opinion that after skilled technical supervision was relaxed in June, 1949, the standard of the measures prescribed steadily declined, and this was fatal to success in fumigation.

FUMIGATION OF COCOA

100. Small fumigation trials have been carried out on cocoa, using HCN in absorbed form, and methyl bromide. In an experimental shed, reasonably leak-proof, of approximately 1,000 cu. ft. capacity, and containing 200 bags of cocoa, a dosage of 30 oz. of HCN per 100 tons was used. A similar trial was carried out with bales of empty bags. Fumigation was unsatisfactory in both trials, possibly owing to the high humidity, but large numbers of *Tribolium* were killed in the free air space.

Results of trials with methyl bromide were extremely good. The free air space rapidly cleared, but gas persisted between the bags for over 24 hours.

SACK DISINFESTATION

101. The policy of treatment of sacks with methyl bromide prior to further use was implemented as a routine by the Department of Marketing and Exports on the advice of the Survey.

Two locomotive smoke boxes on a cement foundation which were originally used for heat sterilisation were adapted for fumigation. Successful treatment of 2,000 sacks daily can be carried out. At Kano, fumigation of empty sacks is done at the same time as routine warehouse treatment.

ADMIXTURE OF INERT AND INSECTICIDAL DUSTS

102. An experiment was conducted at Ibadan, using powdered flowers of pyrethrum admixed with Grade I cocoa. A stack of 182 bags was selected in a typical store loaded with cocoa, in which *Lasioderma* infestation was known to be heavy. The pyrethrum was carefully mixed manually, at four doses, $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, and 1 lb per 140 lb bag, twelve bags being used at each dosage. Treated bags were scattered at random through the stacks, no two treated bags touching.

After eight weeks undisturbed storage, the stack was broken and the four groups of treated cocoa and the control, bulked on the floor and graded separately, a ten pound sample being collected for insect count, and another for moisture content determination. All the cocoa was downgraded into Grade II owing to increase in "weevilly" and mouldy beans. The control had a moisture content of 6.2 per cent., whereas the treated samples all lay in the ranges 8.4 to 9.5 per cent.

The insect samples were stored in the laboratory for one month before the insects present were counted. Few insects were found but *Ephestia* and *Lasioderma* were present in all, and the treated samples were also heavily infested by mites.

Evidently the pyrethrum flowers are hygroscopic and are not effective under the conditions of this experiment. In the drier climate of Kano, admixed pyrethrum was a little more successful.

103. Several experiments were done in Kano (Table X). Pyrethrum was admixed with groundnuts at rates up to 3 lbs. per 189 lb. bag, treated bags being placed adjacently in commercial stacks which remained untouched for periods ranging from 6—12 months. In pyramids a dose of $\frac{1}{2}$ lb. per bag, the only dose used, reduced the damage, estimated as dry weight loss plus groundnut dust, by one half. Inside the stores, even with a dose as high as 2 lbs., only a 55 per cent. reduction of damage was achieved.

104. Similar experiments were done in Kano, using an inert silica dust at the rate of $\frac{1}{3}$ to $\frac{1}{2}$ lb. per bag and with D.D.T. and Gammexane dusts. All reduced damage by about 50 per cent. The inert dust was not used in Lagos because the high humidity reduces efficiency. The synthetic insecticidal dusts were not used there because of the risk of contaminating high quality produce.

The rate at which Gammexane was used (13gm. of D.034 per bag, or 6 parts per million) is 50 per cent. higher than was at the time permitted in Britain, whereas the rate for D.D.T. (8.5 per cent. commercial powder—100 parts per million), is fourteen times higher.

If admixture is limited to external bags, silica and Gammexane are permissible but D.D.T. is not.

None of these dusts was of any use in protecting groundnuts loaded into a warehouse containing a heavy infestation of *Trogoderma*.

105. Tests were done with samples of local minerals, ground in the laboratory using *Trogoderma* larvae. A local diatomite was the only one to show promise, and if efficiently micronised it should be as good as the imported silica tested.

Table X

TESTS USING DUSTS ADMIXED WITH GROUNDNUTS

Site	Treatment	Mean Loss per bag oz.	% Reduction
Pyramid (external bags) ...	Control	211	—
	B.H.C.	113	46
	D.D.T.	97	54
	Pyrethrum	108	49
	Silica (Diatomite)	88	58
Warehouse (external bags) ...	*Pyrethrum		
	½ lb. per sack ...	150	—
	1 „ „ „ ...	83	45
	2 „ „ „ ...	68	55
	3 „ „ „ ...	40	73

*No control used in this experiment.

% reduction in comparison with ½ lb. Pyrethrum.

The results of these tests using admixed dusts are disappointing in that they give little encouragement to the development of this otherwise attractive measure. If a cheap and effective local dust could be distributed to the up-country buying centres there seems no physical reason why the application should not be practicable.

EXTERNAL DUSTING

106. The bags near the outside of two stacks built in stores were treated externally with pyrethrum powder at a rate of 1 oz./sq. ft. during construction. There was no obvious control of *Tribolium* or *Trogoderma* and weight loss was about the same as in untreated stores.

IMPREGNATED BAGS

107. The results obtained using bags impregnated with D.D.T. were disappointing. Experiments in Kano showed that impregnation gave no protection against *Trogoderma.* In Lagos experiments with impregnation using D.D.T. and Gammexane were inconclusive.

SMOKE GENERATORS

108. Warehouses in Nigeria are unsuitable for the use of smoke generators since much of the insecticide escapes through the ventilators and cracks in the fabric even when reasonable attempts are made to block these openings. When used, at least twice the advised dosage was normally applied. Good results, but not complete mortality, were obtained when D.D.T. generators were used against *Tribolium, Calandra* and *Sitotroga* in bagged guinea corn in an air-tight store. Gammexane gave satisfactory kill of moth adults but failed against *Trogoderma* in a normal Kano warehouse, in a railway wagon, and also under tarpaulins in Lagos.

THE TODD INSECTICIDAL FOG APPLICATOR

109. The use of insecticidal fogs or mists applied by a T.I.F.A., is subject to the same disadvantage, i.e., the escape of the insecticide. This was, however, the only means available of treating some premises, which were so overloaded that it was impossible to enter them. The T.I.F.A. produces a fog or mist in

which the particle size can be controlled, but since it puts down only a small deposit of insecticidal film (20-40 mg/sq. ft.), it must be used frequently in premises to give its best results.

110. Fogs, composed of a mixture of 4 lbs. technical D.D.T., 24 oz. L.G. 140 Gammexane, and 4 oz. 25 per cent. pyrethrum concentrate, in eight gallons of diesoline oil, were applied once a month to twenty-one stores. *Tribolium* infestation appeared to be unaffected, but light *Trogoderma* infestations were prevented from increasing. Similar fogs applied under ricksheets to covered pyramids appeared to be useless. Similarly a fog applied in the open at dusk and allowed to drift over uncovered pyramids, did not affect the insects flying at the time. On one occasion, however, a fog was applied to two pyramids immediately after spraying with aqueous suspension. Oil drops were obviously deposited on the sacks, and those pyramids alone on this site remained free of *Trogoderma.*

The phosphorus insecticides H.E.T.P. and T.E.P.P. used as fogs and as sprays were ineffective.

OIL SPRAYS

111. Oil sprays were applied to warehouse walls using the T.I.F.A. In Lagos, tests with oil sprays showed immediate absorption into concrete surfaces; no further tests were made. In Kano oil sprays were used when *Trogoderma* larvae were obvious on walls.

Pyramid plinths and the outside walls of warehouses were sprayed with diesoline oil immediately after the removal of *Trogoderma* infested groundnuts.

TRAPPING

112. Trapping, using sticky "Ate" strands, has been a routine measure in cocoa stores in Nigeria for some years (Golding, 1941). The Survey has used soap solution traps to obtain evidence on the incidence of the various species. All the female moths so caught, both in Lagos and in Kano, were fertilised, and most had laid the majority of their eggs. Trapping seemed to cause no reduction in numbers.

In the opinion of the Survey, this method is unlikely to be of any importance in control, and certainly the present policy of placing traps around cocoa and ignoring other produce stored adjacently is quite illogical.

The best way to use traps would be to cover all ventilation openings with sticky screens, to intercept the nightly migrations to and from the stores.

CONTAMINATION AND TAINT

113. The contamination and taint of produce likely to be caused by the control measures used was investigated for spraying of premises, spraying of bagged produce, admixture of insecticidal dusts, and the use of impregnated bags. In all, there was significantly more absorption of Gammexane than of D.D.T.

During spraying of stores with aqueous suspensions there is liable to be considerable run-off resulting in a high insecticide concentration on the floor.

The contamination caused by bulking and grading cocoa on a treated floor was investigated by spraying a floor with aqueous suspensions of D.D.T. and Gammexane at the rate of 600 mg./sq. ft. and 40 mg. gamma B.H.C./sq. ft. respectively.

Absorption by the whole beans amounted to 2.8 parts per million D.D.T., and 1.9 parts per million total isomers B.H.C., after being in contact with the floor for one week, which is much longer than is normal in practice. It is likely from results quoted below (Table XI), that most of the insecticide was localised in the testa.

114. Cocoa was also used to investigate the effect of bag impregnation. Impregnated bags containing 3.45 per cent. D.D.T. and 1.65 per cent. B.H.C. (total isomers), respectively, were filled with cocoa at a creek port, and after a very short period of storage were transported by lighter to Lagos, where the bags and the cocoa were analysed three weeks later. The insecticide content of the bag material had fallen to 2.8 per cent. D.D.T. and 0.9 per cent. B.H.C. The uptake of insecticide by the cocoa is given in Table XI., which shows the distribution between the testa, used for cattle cake, and the cotyledon, used for cocoa.

TABLE XI

ABSORPTION BY COCOA BEANS OF D.D.T. AND B.H.C. FROM IMPREGNATED BAGS

(In parts per million)

	p.p.m. D.D.T.			p.p.m. B.H.C. (total isomers)		
	Whole	Testa	Cotyledons	Whole	Testa	Cotyledons
(i)	1·07	4·58	0·68	1·39	3·1	1·2
(ii)	1·1	4·61	0·71	1·1	2·2	1·0
(iii)	0·98	4·43	0·61	1·28	2·9	1·1
Mean	1·05	4·54	0·67	1·26	2·7	1·1

115. The contamination caused by spraying aqueous suspensions of insecticide on to bags of groundnuts was investigated in Kano by treating two commercial stacks with very high doses, namely 725 mgs. D.D.T./sq. ft., and 39 mgs. gamma B.H.C./sq. ft. respectively. These levels are over twice those used in practice.

After six months normal storage, twenty bags each presenting the maximum surface to the spray were selected from each pyramid and expressed locally by the commercial method. The oil and cake were analysed for insecticide, the results being given in Table XII.

Since outside bags only are sprayed, and form only one quarter of the total number in a pyramid, and since all the bags are thoroughly mixed together in transit, the net contamination of the whole pyramid is only about one-sixth of that found in the bags analysed. The corrected net contaminations are also given in Table XII. These are well within their statutory limits, applicable in the United Kingdom.

TABLE XII

CONTAMINATION OF GROUNDNUT CAUSED BY SPRAYING AQUEOUS SUSPENSIONS

(In parts per million)

	D.D.T.		B.H.C. (total isomers)	
	Oil	Cake	Oil	Cake
Contamination of sample ...	27 ppm	5·5 ppm	14 ppm	6 ppm
Net contamination of pyramid	4.7 ppm	1·0 ppm	2·5 ppm	1·0 ppm

No odour or unusual flavour could be detected.

116. D.D.T. and Gammexane D.034 dusts were admixed with groundnuts at levels of 600 parts per million and 58 parts per million B.H.C. (total isomers). Since groundnuts apparently receive no processing before expression, all this

admixed dust would go into the final products. In the laboratory, samples of these nuts were thoroughly washed, but 20 parts per million D.D.T. and 33 parts per million B.H.C. were still retained by the nuts, that is about 4 per cent. of the D.D.T. and 60 per cent. of the B.H.C. originally applied.

117. In general, it may be said that routine spraying of empty stores and bagged produce is desirable, and unlikely to cause contamination, but admixture of insecticidal dusts at effective levels is ruled out on this score. With cocoa, caution must be exercised in the use of B.H.C. owing to the risk of taint.

RECOMMENDATIONS TO THE NIGERIAN COMMODITY BOARDS

(A) IMPROVEMENTS IN STORAGE PRACTICE, INCLUDING HYGIENE

Orderly stowage and continuous attention to cleanliness are essential if control of storage pests is to be achieved, no matter how many additional methods are used. Technical supervision of those immediately concerned, i.e., store clerks, headmen and labourers, has only too frequently been lacking. The introduction of grading in cocoa is a routine which automatically improves the general standard of storage, but much of this is lost again in the congested port transit sheds.

The following hygiene measures, many of them reiterated, should be firmly enforced:

(1) Thorough cleansing and lime-washing of stores when empty. Routine sweeping and, where feasible, vacuum cleaning should be practised during storage.

(2) Routine emptying of all transit stores twice yearly to permit of cleaning, special attention being given to rafters, ledges and cracks in walls or floors which harbour insects. Rejected sweepings and unsaleable parts of a crop should be promptly and meticulously destroyed.

(3) Always store commodities as dry as possible and keep dry. The provision of dunnage should never be neglected.

(4) Stacks should be as large as possible to reduce to a minimum the surface exposed to infestation. Thermal self-sterilisation tends to occur inside large stacks and may be exploited. (The death point of most insects is at 42°-45°C.).

(5) Inspection walks 2 ft. wide should be left round the walls of all commodity stores, and space under the rafters, so that control measures can be applied when necessary.

(6) Evacuation of commodities in order of reception should be ensured, except that infested parcels may require priority of dispatch. Avoid prolonged storage, especially in producers' or middlemen's stores. (Para. 60-62.)

(7) Commodities should be stored separately, and new crop away from old crop. If a common infestation affects different products in the same store, the same insecticidal measures should be applied to each commodity.

(8) The retention of parcels of commodities for mixing in with higher grade or a subsequent crop to secure higher price must be discouraged.

(9) Second-hand bags should always be fumigated before re-use.

(B) PRACTICAL CONTROL MEASURES

(*a*) *General*

(1) D.D.T. or B.H.C. in aqueous suspension should be applied twice yearly to all internal surfaces of emptied storage premises.

(2) Application should be made with a power sprayer of the Lister S.S.2 orchard type, using a nozzle giving a flat fan-like spray. In closed and loaded stores the Todd Insecticidal Fog Applicator will help to reduce serious infestations.

(3) A layer of pyrethrum, D.D.T., B.H.C., or an inert dust may be laid round the base of walls in stores.

(4) D.D.T. and B.H.C. should not be applied directly to unbagged foodstuffs in bulk.

(5) Fumigations, preferably with methyl bromide, should be carried out only by well-trained technical staff, or by specialised contracting firms, in view of the skill required in application. Staff required to handle poisonous fumigants should be properly covered by insurance. Small scale fumigations with carbon bisulphide, or ethylene dichloride, may be carried out by unskilled workers without undue risk.

(b) Special measures for the Southern Provinces of Nigeria

(1) In warehouses used for the storage of cocoa, D.D.T. sprays should be used against *Lasioderma,* and B.H.C. for heavy *Ephestia* infestations, with due precautions as to taint. Applications should give deposits of 200—300 mg/sq. ft. of D.D.T. and 8—12 mg/sq. ft. of gamma B.H.C.

(2) Applications should be made to stores during the empty period, at the cocoa buying moratorium before the opening of the main crop season. They should be uniform, and without excessive run-off. The second application should follow six months later, at the end of this season.

(3) Spraying should be extended to palm kernel stores where these adjoin the cocoa stores, and eventually to all stores.

(4) All transit stores at the ports should be emptied and sprayed every six months as a routine. The higher dosages necessary for groundnuts should be used.

(5) "Ate" strands and other existing routine methods should be retained if only to give an indication of growing infestations.

(6) Fumigation with methyl bromide of cocoa stacks *in situ* in under-cover storage by the same method as recommended for outdoor pyramids should be tried. (Para. c. 8.)

(7) Provision of proper concrete fumigation chambers to ensure treatment of all used and repaired bags with methyl bromide, should be made at Lagos and extended to Port Harcourt and the larger up-country centres. Steps must be taken to ensure that clean fumigated sacks are stored separately from dirty sacks. Such chambers could be used at Lagos (Apapa) for the fumigation of infested parcels of special products such as Capsicums prior to shipment.

(c) Special measures for the Northern Province (Groundnut Areas)

(1) It is recommended that a maximum tonnage of groundnuts be stored in pyramid or cottage-shaped stacks in the open, or under a cover of the Dutch barn type. This would release warehouses for the storage of other commodities.

(2) No store heavily infested by *Trogoderma* should be used for food commodities for at least one year.

(3) Stacks, properly numbered to aid identification, should be as large as possible (1,500—2,000 tons), up to a maximum width of 50 ft., in order to increase tonnage/surface ratio.

(4) Bases of plinths should be of cinders, and should extend 18 inches beyond the bags to facilitate fumigation. Dunnage in the form of a complete layer of bags of groundnut husk will prevent water damage in pyramids and stores.

(5) Plinths, working areas, and outsides of stores should be sprayed with Diesoline oil.

(6) Pyramids should be sprayed once at dusk before covering with aqueous suspensions of D.D.T. at 360 mg/sq. ft., or of B.H.C. at 12 mg/sq. ft. of gamma B.H.C. Dosages for warehouses before stacking nuts, should be increased for D.D.T. to 400 mg/sq. ft.

(7) Where heavy *Trogoderma* infestation has been experienced, only B.H.C. should be used.

(8) Fumigation of pyramids under dinghy sheeting, using the Peverett method, should be done whenever commercially important infestation is suspected. The assessment of infested conditions should be done by trained staff, as recommended below (Administrative measures, No. 7). Until *Trogoderma* is under satisfactory control, it should be assumed that all incoming nuts are infested. The recommended dosage is at the rate of 100 lbs. of methyl bromide per 750-ton stack (and *pro rata*) subject to experimental confirmation.

(9) Routine fumigations should continue at Kano in two of the existing stores, to be sealed in accordance with the Peverett recommendations. Frequent inspection of the sealing, and making good where required, is essential. The dosage of 30 lbs. of methyl bromide per 150 tons should be used, pending further experiment.

(10) The prevention of the spread of *Trogoderma* in winnowing dust, residues, sacks, rick sheets, and even in books and clothing, should be impressed on all concerned. Sieves should be boxed in, and storage residues burnt promptly.

(C) ADMINISTRATIVE MEASURES

The following recommendations refer mainly to the marketing, storage and transport of groundnuts. The existing system of cocoa grading is a guarantee of quality standards, and losses in palm kernels during storage are small.

(1) It is considered essential that the quality of groundnuts be improved by reducing the proportion of broken nuts, dust and infestation in the Kano area. We see no alternative to some system of grading. Whether this should be voluntary by buying agents or laid down and enforced by legislation, a higher standard of acceptance by the U.K. buyer should be the final arbiter.

(2) Possible methods of achieving the above recommendation are: —

(*a*) A higher price to be given for samples containing less than 10 per cent. of broken pieces to encourage hand-shelling.

(*b*) Introduction of sieves (6-mesh) to eliminate small broken pieces before bulking.

(*c*) A drive to introduce proper shelling machinery.

(3) Prevention of admixture of old with new crop nuts, by fixing an upper limit of say 1.0 per cent. free fatty acid (as oleic acid) for whole nuts, sampled as they come into the Agent's stores. Frequent spot tests would tend to reveal parcels of nuts which have been stored for one year after shelling. Means should similarly be sought for preventing the mixing of light-weight cocoa crop with standard weight.

(4) The practice of giving railment priority to owners of groundnut stocks infested with *Trogoderma* should be modified. Far from being regarded as an advantage, infestation of a stack by *Trogoderma* should be penalised in the price paid to the owner. One step towards such a change would be the transfer of responsibility for railing to the Department of Marketing and Exports.

(5) Congestion of storage sites should be eased by the creation of an alternative storage area on the railway outside Kano. Systematic evacuation of groundnuts area by area should be adopted.

(6) Groundnuts originating in French Territories should be treated in the same way as Nigerian nuts during storage or transport in Nigeria. The same procedure should apply to nuts bought from the Board for local expression of oil.

(7) Produce Officers and Examiners should be trained in the practice of insect detection, identification and control, and should have closely associated with them special gangs trained in the application of routine control measures. These gangs should work from suitable centres in the marketing areas and at ports.

(8) In the South, the co-operation of the tobacco industry should be sought in overcoming the joint problem of *Lasioderma* infestation in tobacco and cocoa.

(D) FUTURE RESEARCH

The West African Pest Infestation Survey has done much of the essential introductory work, and this Report forms a basis on which further research work can be planned.

The West African Pest Infestation Research Unit has already been set up to continue this work under the Director of Marketing and Exports, and it is essential that it should be able to concentrate on research on storage pests, the losses they cause, and means for their control. It should not be expected to undertake the supervision of control measures, which work should be done by separate staff trained for the purpose by the Research Unit, and carrying out their recommendations. Administrative duties must be confined to the minimum essential to the operation of a self-contained unit.

Much of the needed work is basic and common to the whole world. Whilst much of it can be better done in laboratories with more adequate facilities than are at present obtainable in West Africa, basic field research should always be attempted locally. The programme of work is best determined by the staff which is to do it, and the following proposals are made chiefly to show the problems which are considered most urgent.

(*a*) *Field Biology*

A continuous watch must be kept on the insect population in storage premises to note the status of pests under changing conditions. Intensive observations need to be made in farmers' and brokers' storage premises and at buying centres. Activity of almost all species is greatest at or near dusk, and attempts at measuring variations in numbers both from hour to hour and at dusk should be made over a period of months.

Methods for ascertaining the distribution of insects in produce and buildings should be developed. There appears to be no reliable information concerning commercial bags of produce in this relation.

Specific subjects under this heading are: —

(i) A reliable method of estimating insect numbers is needed, and, to this end, methods of trapping *Trogoderma* should be evolved and the CO_2 method investigated. (Howe and Oxley, 1944.)

(ii) The status of *Necrobia* as a pest of palm kernels, the non-occurrence of *E. elutella* in West Africa, and the points of origin of *Lasioderma* infestation in cocoa should be determined.

(iii) The interaction of *Trogoderma* and *Tribolium* under various conditions should be worked out by an intensive study of the field biology of both species. A similar study is required to ascertain the depth of penetration into stacks of *Lasioderma* and *Trogoderma*.

(iv) The feeding habits of *Ephestia cautella* and *Lasioderma* in their particular relation to damage to the cocoa bean require clarification.

(*b*) *Storage Conditions*

It is important that environmental conditions of insects in food stores should be defined with a greater precision than has hitherto been possible. In particular, the following lines of work should be pursued: -

(i) The temperature gradients inside stacks should be measured by means of thermo-couple ropes in all commodities and correlated with insect behaviour.

(ii) Simple methods of studying the relationship between moisture content of commodities and the humidity of the surrounding air should be developed. Particular attention should be paid to Solomon's cobalt thiocyanate paper and similar methods, suitable for field use. (Solomon, 1945.)

(*c*) *Chemical Control*

Investigation of the basis for the effectiveness of D.D.T. and B.H.C., pyrethrum and other insecticides in their various formulations must be a prelude to progress in the practical application of insecticides in storage in Nigeria. Particular problems include: —

(i) Chemical determinations of actual deposits resulting from various theoretical rates of application, and of their persistence should be linked with biological tests of insecticidal efficiency.

(ii) A comparison of the efficiency of oil and water sprays and dusts under all storage conditions. The value of pyrethrins applied direct to bagged produce or in oil mists should be investigated. The stabilisation of pyrethrin formulations is an important problem for the Tropics.

(iii) The use of dusts for external application to bags, particularly at the periphery of stacks, should be thoroughly tested. The development of locally produced dusts, such as Bornu diatomite, for admixture is a promising line of work.

(iv) The distribution of dusts in sacks treated with the Craven injector gun should be determined.

(*d*) *Fumigation*

The following specific points are worthy of attention: —

(i) Information is required on the gas concentration and distribution during fumigation, especially in 1,500-ton pyramids of groundnuts and in cocoa stacks.

(ii) Biological tests at sample points on the concentration-time products required to kill the various pest species in the field, should be made.

In addition to the above tentative programme, much useful research work on the fundamental aspects of Nigerian pest infestation could be done in the more fully equipped laboratories in the United Kingdom. Problems such as the absorption of synthetic insecticide by commodities, completed biological studies on *Lasioderma*, *Trogoderma* and *Ephestia*, the feeding habits of *Necrobia*, and the determination of critical concentration-time products in the fumigation of the main pests, could well be farmed out to Universities and research institutions.

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APPENDIX

A LIST OF THE COMMONER AND MORE IMPORTANT STORAGE INSECT PESTS FOUND IN NIGERIA BY THE SURVEY

I. Southern Nigeria

(*a*) Major Pests

Species	Usual Foods	% of shipments of cocoa found infested by Infestation Control Division (Oct. 1949 to Jan. 1951)
Araecerus fasciculatus (de G.) ...	Cocoa, Maize	35
Calandra oryzae (L.)	Maize	1
Ephestia cautella (Wlk.) ...	Cocoa, Palm kernels cereals	90
Lasioderma serricorne (F.) ...	Cocoa, Tobacco ...	50
Necrobia rufipes (de G.) ...	Palm kernels	48

(*b*) Minor Pests

Species	Usual Foods	% of shipments of cocoa found infested by Infestation Control Division (Oct. 1949 to Jan. 1951)
Ahasverus advena (Waltl.) ...	Mould	28
Alphitobius laevigatus (F.) ...	Wet produce	1
Aphanus sordidus (F.)	Benniseed (predator ?) ...	1
Carpophilus spp.	Mould	15
Laemophloeus ferrugineus (Steph.)	Cocoa debris	21
Oryzaephilus mercator (Fauv.) ...	Palm kernels	12
Sitotroga cerealella (Ol.) ...	Cereals	0
Tribolium castaneum (Herbst.) ...	Debris	63
Corcyra cephalonica (Stt.) ...	Cocoa	14
Tenebroides mauretanicus (L.) ...	Palm kernels	15
Pachymerus lacerdae (Chevr.) ...	Palm kernels	0

II. Northern Nigeria

(*a*) Major Pests

Species	Usual Foods	% of shipments of shelled groundnuts found infested by Infestation Control Division in the U.K. (April 1949 to Jan. 1951)
Calandra oryzae (L)	Guinea corn	2
Corcyra cephalonica (Stt.) ...	Groundnuts	49
Ephestia cautella (Wlk.) ...	Groundnuts, guinea corn	83
Plodia interpunctella (Hb.) ...	Groundnuts	34
Rhizopertha dominica (F.) ...	Guinea corn	0
Sitotroga cerealella (Ol.) ...	Guinea corn	1
Tribolium castaneum (Herbst.) ...	Groundnuts, guinea corn	100
Trogoderma granarium (Everts) ...	Groundnuts, guinea corn	47

(*b*) Minor Pests

Species	Usual Foods	% of shipments of shelled groundnuts found infested by Infestation Control Division in the UK. (April 1949 to Jan. 1951)
Alphitobius laevigatus (F.) ...	Wet food	9
Aphanus sordidus (F.)	(predator ?)	0
Carpophilus spp.	Mould	7
Laemophloeus ferrugineus (Steph.)	Groundnuts	32
Lasioderma serricorne (F.) ...	Cigarettes	3
Oryzaephilus mercator (Fauv.) ...	Groundnuts	32
Palorus spp.	Groundnuts	1
Tenebroides mauretanicus (L.) ...	Wet groundnuts, predator	39
Thermobia sp.	Debris	3
Tribolium confusum.	Groundnuts	3

III. Cross Infestation

Cross infestation in transit is illustrated by the records of *Ahasverus advena* (12%) and *Necrobia rufipes* (48%) on groundnut shipments at U.K. ports although these species were not found in Northern Nigeria. Similarly the records of the typical groundnut pests *Tribolium castaneum* (63%), *Corcyra cephalonica* (14%), *Plodia interpunctella* (10%) and *Tenebroides mauretanicus* (15%) on cocoa shipments indicates cross infestation at Nigerian ports or on shipboard.

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